CIRCUMFERENTIAL PRESSURE DISTRIBUTION ON

AN INCLINED BODY OF REVOLUTION

by

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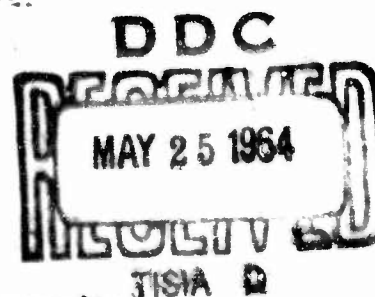
ABSTRACT. A summary is presented of the results obtained from wind-tunnel tests of a blunt-nosed body of revolution on which the circumferential pressure distributions at various stations along the body were determined. An empirical equation for calculating the circumferential pressure distributions on the cylindrical portion of the body is developed and compared with the experimental data.

U.S. NAVAL ORDNANCE TEST STATION

China Lake, California

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U. S. NAVAL ORDNANCE TEST STATION

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C. BLENMAN, JR., CAPT., USN   WM. B. McLEAN, PH.D.
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FOREWORD

As part of a broad study on applied research in aerodynamic heating, this report is written to document the results of a study on the circumferential pressure distribution on a blunt-nosed body of revolution. The over-all study is specifically related to heat transfer to a body at angle of attack.

Wind-tunnel tests were conducted at Massachusetts Institute of Technology in October 1959 under Contract N123(60530)20601A. Again in June 1962, wind-tunnel tests were made at the U. S. Naval Missile Center, Pt. Mugu. Portions of the data from these tests provided the basis for this study at the U. S. Naval Ordnance Test Station. The work discussed here was carried out intermittently from July 1959 to July 1963 and was funded under the Bureau of Naval Weapons Task Assignment 502-726-61010-01-060, RMGA-53-406/216-1/F009-10-001, RMGA-41-039/216-1/F009-10-001, and RMGA-81-039/216-1/F009-10-01, Problem Assignment 2.

From the technical standpoint, this report has been reviewed for accuracy and completeness by George E. Sutton of the University of Nevada and Consultant to this Station, and Bruce E. Larock of the Weapons Development Department.

Directly related to this report and also published at this Station under the over-all aerodynamic heating study is NAVWEPS Report 8048, NOTS TP 3050, entitled "Summary of Results of Pressure Coefficient Calculations for a Spherical-Tipped Tangent-Ogive Body."

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Weapons Development Department
26 March 1964

Under authority of
Wm. B. McLEAN
Technical Director

ii

CONTENTS

NOTATION

A   Empirical constant

C_p Pressure coefficient

g   "Gravitational constant"

p   Static pressure

q   Dynamic pressure, $1/2 \, \rho V^2$

U   Freestream velocity in potential crossflow

V   Freestream velocity

v_a Axial velocity component due to angle of attack

v_c Crossflow velocity component due to angle of attack

v_d Downwash velocity component defined by Eq. 7

v_R Resultant velocity defined by Eq. 8

v_r Resultant velocity defined by Eq. 6

v_t Tangential velocity defined by Eq. 3

w   Specific weight of fluid

z   "Elevation head" of fluid

α Angle of attack

θ Circumferential angular position measured from windward station

φ Circumferential angular position measured from downward station

ρ Fluid density

Subscripts

1, 2   Refer to two points in the flow upstream and downstream, respectively

INTRODUCTION

The pressure distribution on bodies of revolution has long been a subject for intensive studies, both theoretical and experimental, resulting in large amounts of information being assembled and reported. Analysis and measurements have been made for bodies of numerous shapes over wide ranges of flow conditions. Fortunately for those in need of this information, a large part of the results have been conveniently summarized in publications such as Ref. 1 and made available for general use.

In most of the work, the pressure distribution studies on bodies of revolution have been carried out by investigating the longitudinal variation of the static pressures. Virtually all of the theoretical methods are based on procedures which develop the pressures on the body surface along a line extending from the nose to the tail at points located in a single plane. For axisymmetric bodies of revolution at zero angle of attack, the results obtained adequately describe the pressures over the entire surface. Also, for bodies of revolution at very small angles of attack, similar procedures have been developed wherein valid results were obtained since the transverse flow component across the body, which tends to distort the circumferential distribution, is small and almost negligible. Most of the solutions to the body of revolution problem have been those in which the angle of attack was small and, as a result, information on the circumferential pressure distribution has been limited. This situation is typically illustrated by the number of pages presenting circumferential pressure distribution data (Ref. 1), whereas only a few pages out of several hundred are devoted to the subject. It must be admitted, however, that the subject of pressure distributions and associated materials is contained in approximately one-quarter of the text, and the remainder is concerned with other matters pertaining to the forces and moments on bodies of revolution.

Some of the theoretical analyses are adaptable for use in estimating the circumferential pressure distributions on bodies of revolution. For sharp-nosed bodies, the theoretical method of Ref. 2 gives excellent results on and near the nose, but with increasing distance from the nose on the downstream side of the body at angle of attack, this method breaks down significantly. From the practical standpoint, this method has the disadvantage of being applicable only to sharp-nosed bodies and requires relatively complex numerical steps for its solution.

For many requirements such as the estimation of aerodynamic heating effects, pressures of only fair accuracy in magnitude and distribution patterns (both longitudinal and circumferential) of reasonable validity are needed. For such purposes, a simple empirical method for predicting the distribution pattern would be adequate.

This report discusses part of a continuing study on the aerodynamics of the body of revolution at angle of attack, being conducted at the U. S. Naval Ordnance Test Station (NOTS), China Lake. As part of the overall program, heat-transfer studies on a blunt body at angle of attack were conducted for NOTS in the Massachusetts Institute of Technology (MIT) Naval Supersonic Laboratory, the results being presented in Ref. 3. Since pressure data were obtained in the course of the experimental work, a brief study of the data was made in an attempt to develop some understanding of the circumferential pressure distributions on bodies at angle of attack.

Supplementary experiments were conducted at the Aerodynamic Test Laboratory, U. S. Naval Missile Center (NMC), Pt. Mugu, Calif., in which just the pressure distribution measurements were made to provide additional information to assist in the interpretation of the MIT data.

Discussed here is the treatment of the data obtained in these wind-tunnel programs. Briefly described are the model configuration and the pressure instrumentation systems used, and an empirical treatment of the circumferential pressure distribution. For purposes of reader convenience, Appendix A acts as an index to the pressure taps used in the MIT and Pt. Mugu data which appear in tabular form in Appendixes B and C.

WIND-TUNNEL TEST PROGRAM

The experimental pressure data considered in this report were obtained from two sources. The first group of data (Appendix B) was obtained as a by-product of the heat-transfer experiments conducted in the MIT Naval Supersonic Laboratory, Hot Core Facility (Ref. 3).

As a result of a preliminary examination of the pressure data, plotted in polar coordinates to display the circumferential distributions at each pressure tap station, another wind-tunnel test was conducted at Pt. Mugu to verify the data obtained in the MIT experiments. This was done because of the somewhat unusual curves which were obtained in the initial polar presentations. This aspect of the data will be discussed later in the report.

The second wind-tunnel test program was conducted in the supersonic wind tunnel at the Aerodynamic Test Laboratory at NMC. These experiments served to determine if wind-tunnel flow characteristics in MIT tunnel were responsible for the apparently erratic pressure data

by duplicating, to a large extent, the pressure measurements in a
different wind tunnel. The tests showed that this was not the case and,
at the same time, provided additional data for the work reported here.

MODEL CONFIGURATION AND INSTRUMENTATION

The body of revolution used in the wind-tunnel tests is described
in Ref. 3, and locations of the pressure-porting instrumentation are
also given. Because only the pressure instrumentation is of concern
here, just a brief description of the model is given in this report. The
model configuration is shown in Fig. 1, and the dimensional coordinate
values are listed in Table 1. The model with pressure tap stations is
shown in Fig. 2, and Table 2 lists the pressure tap locations. The
model was constructed of 304 stainless steel; its nominal length was
23 inches and the maximum body diameter was 2.500 inches. The
0.700-inch-radius hemispherical nose was faired into the forward ogive
which, in turn, was faired into the constant-diameter cylindrical body.
The same model was used in both the MIT and the Pt. Mugu wind-tunnel
tests. In the MIT tests, the pressure taps were connected to the multi-
tube manometer board and the data were recorded photographically. In
the Pt. Mugu experiments, the pressure taps were connected to electri-
cal pressure transducers and the data were recorded by an analog-to-
digital readout system.

EXPERIMENTAL PROCEDURES AND DATA REDUCTION

The MIT wind-tunnel tests were conducted in the Naval Supersonic
Laboratory, Hot Core Facility in October 1959. This Hot Core Facility
has a unique high-temperature core in the supersonic windstream of the
wind tunnel used to obtain aerodynamic heating data. (The arrangement
and operation of this wind-tunnel feature are described in Ref. 4.)

The nominal experimental conditions in the test section provided a
stagnation temperature of 700°F, a longitudinal Reynolds number of
0.2×10^6 per foot, and a dynamic pressure of 5 psia. The hot core
freestream Mach number was nominally 3.65. The experimental pro-
cedures used in this test program are described in detail in Ref. 3, but
the run schedule for these tests is given in Appendix B (Tables 4-27).

The Pt. Mugu wind-tunnel test program was conducted in June
1962 in the supersonic wind tunnel of the University of Southern Cali-
fornia Engineering Center, Aerodynamic Test Laboratory, NMC.
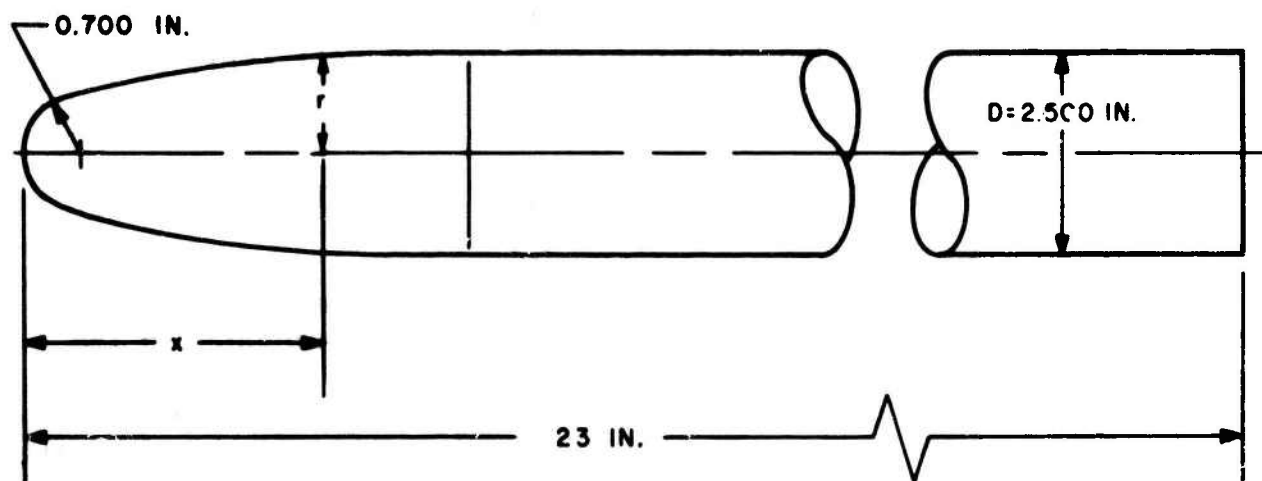
FIG. 1.   Model Configuration.   (Table 1 shows the values of x and r in inches.)

TABLE 1.   Model Coordinates

Dimensional coordinates, inches			
x	r	x	r
0	0		
0.555	0.685	3.000	1.060
0.750	0.727	3.250	1.089
1.000	0.777	3.500	1.117
1.125	0.798	3.750	1.143
1.250	0.820	4.000	1.169
1.500	0.862	4.250	1.192
1.750	0.900	4.500	1.211
2.000	0.935	4.750	1.228
2.250	0.968	5.000	1.2415
2.500	1.000	5.250	1.249
2.750	1.030	5.500	1.250
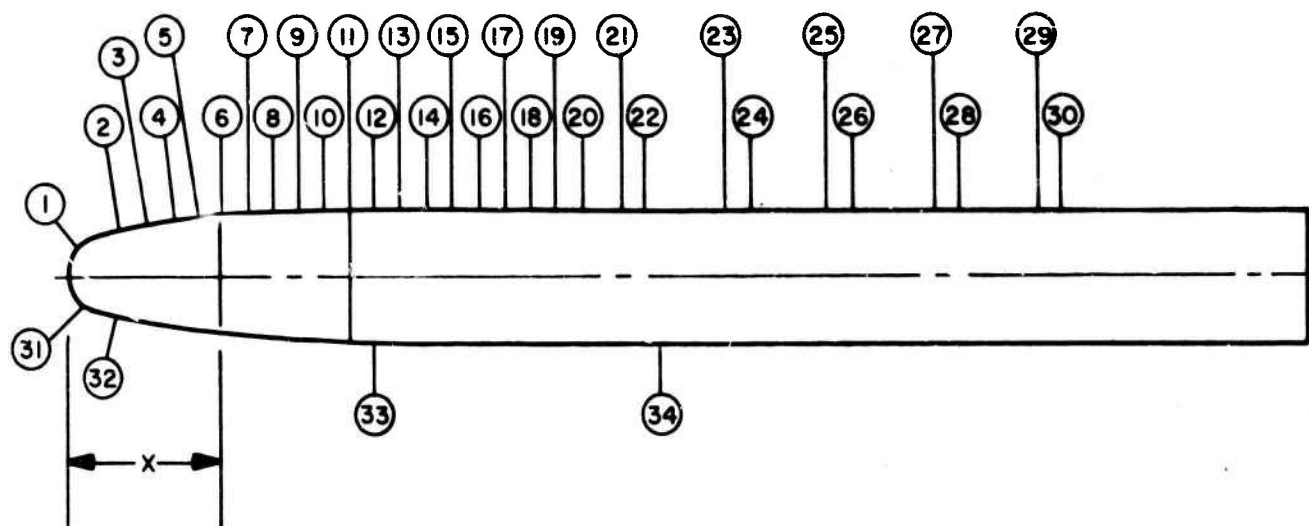
FIG. 2. Pressure Tap Stations. (Locations, in inches, are shown in Table 2.)

TABLE 2. Pressure Tap Locations

Tap no.	Dimensional coordinates		Tap no.	Dimensional coordinates	
	x, inches	x/D[a]		x, inches	x/D[a]
1	0.200	0.080	18	8.987	3.595
2	1.000	0.400	19	9.513	3.805
3	1.525	0.610	20	9.987	3.995
4	1.975	0.790	21	10.763	4.305
5	2.525	1.010	22	11.237	4.495
6	2.975	1.190	23	12.763	5.105
7	3.520	1.408	24	13.237	5.295
8	3.980	1.592	25	14.763	5.905
9	4.515	1.806	26	15.237	6.095
10	4.985	1.994	27	16.763	6.705
11	5.513	2.205	28	17.237	6.895
12	5.987	2.395	29	18.763	7.505
13	6.513	2.605	30	19.237	7.695
14	6.987	2.795	31	0.200	0.080
15	7.513	3.005	32	1.000	0.400
16	7.987	3.195	33	6.003	2.401
17	8.513	3.405	34	11.450	4.580

[a] D = 2.500 inches in diameter.

Nominally, these test conditions were Mach number 3.06, a longitudinal Reynolds number of 7.5 to 8.9 x 10^6 per foot, and a dynamic pressure of approximately 14.75 psia. The run schedule for these tests is given in Appendix C (Tables 28-43).

The data reduction process for the MIT data involved the manual reading of the photographically recorded manometer data and the conversion of the measured fluid levels into pressures and coefficients by means of appropriate algebraic relations and constants. Since the fluid levels are measured in absolute terms, the maximum reading and conversion errors in this type of data recording and reduction tend to remain relatively constant over the entire range of readings. For these data, the maximum error in the pressure coefficient is estimated to be of the order of ±0.03 with the probability that for most of the data points, the error will be about half the maximum.

Since pressure transducers were used to measure the Pt. Mugu data, the possible errors in the data differ from those of the MIT data in the sense that the maximum errors are of a constant percentage, as opposed to the constant absolute magnitude obtained from fluid manometer data. After data reduction, transducer errors generally constitute about 2 or 3% of the maximum transducer rating. For the Pt. Mugu data, the error in the coefficients approximates an order of 0.02 to 0.03, or roughly ±0.015, which is about half that of the MIT data but of the same order of magnitude.

DISCUSSION OF EXPERIMENTAL RESULTS

Representative plots of the pressure coefficient data obtained from the MIT tests are presented in Fig. 3-7. Plotted in Cartesian coordinate form, these curves are typical of pressure plots in general, and any anomalies which may be present in the circumferential pressure distribution are not readily apparent. The curves show the longitudinal pressure distribution for several of the circumferential positions run in the tests and at four angles of attack.

Each of the curves shows the typical high pressure at the nose, nominally the stagnation pressure, and the rapid decrease in pressure along the surface to the region of junction between the nose ogive and the cylindrical body. Theoretically, the pressure coefficients along the cylindrical portion of the body would be zero, but due to the experimental errors and the presence of viscous and real gas effects, the values shown by the plotted data are nonzero.

FIG. 3. Longitudinal Pressure Distribution (φ = 0 Deg), MIT Data.
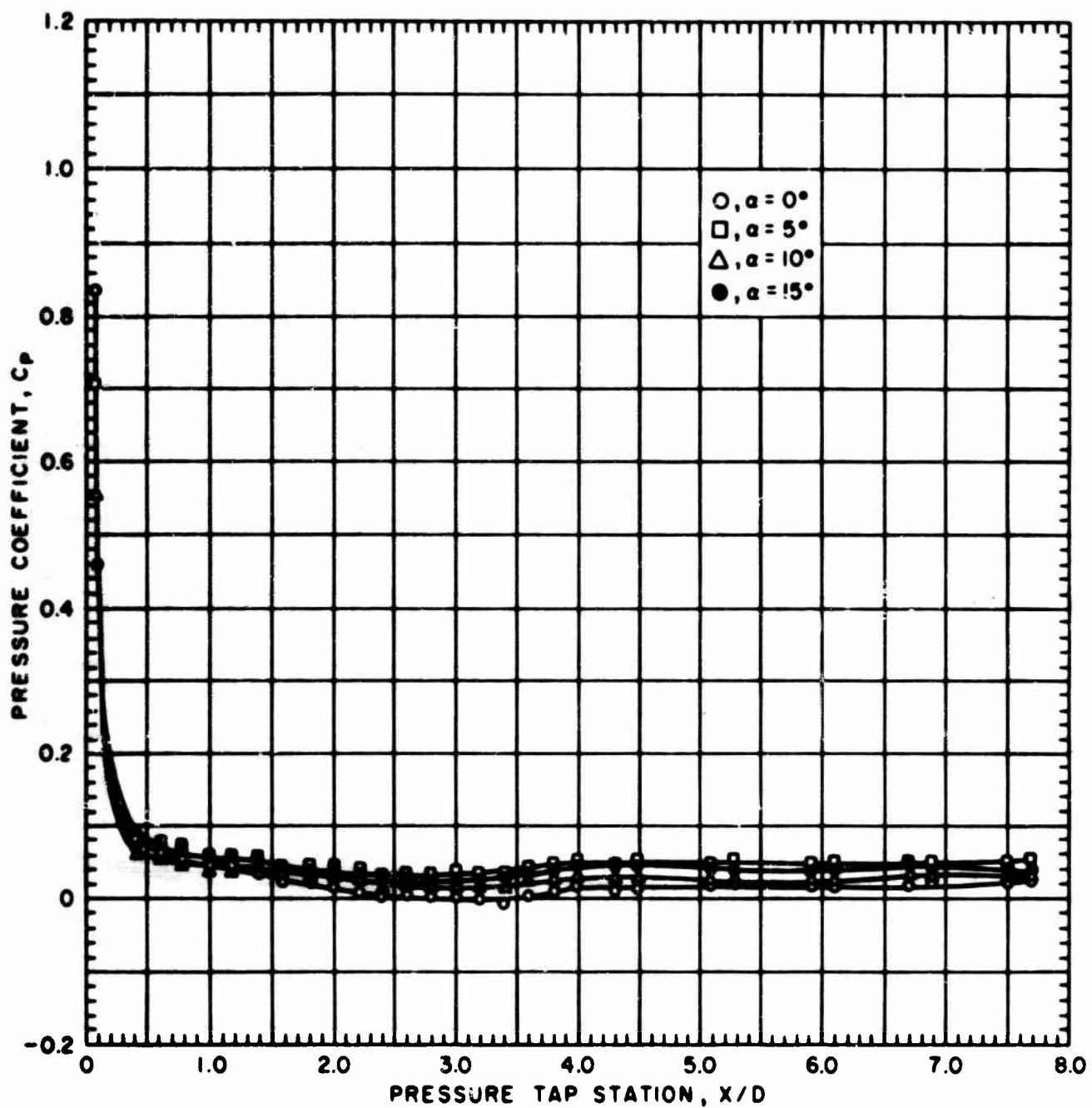
FIG. 4. Longitudinal Pressure Distribution (φ = 30 Deg), MIT Data.

FIG. 5. Longitudinal Pressure Distribution (φ = 60 Deg), MIT Data.
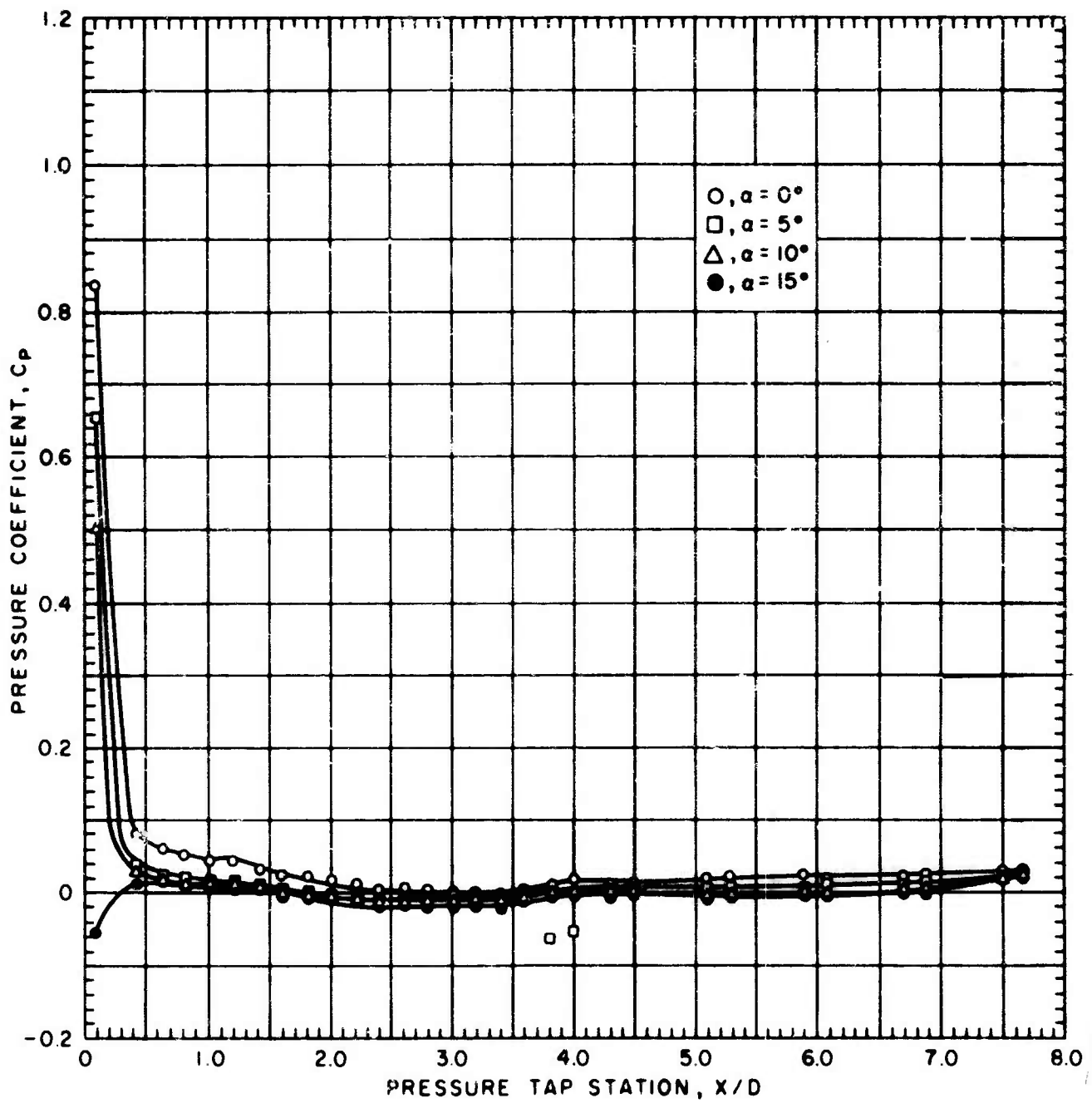
FIG. 6.   Longitudinal Pressure Distribution (φ = 90 Deg), MIT Data.
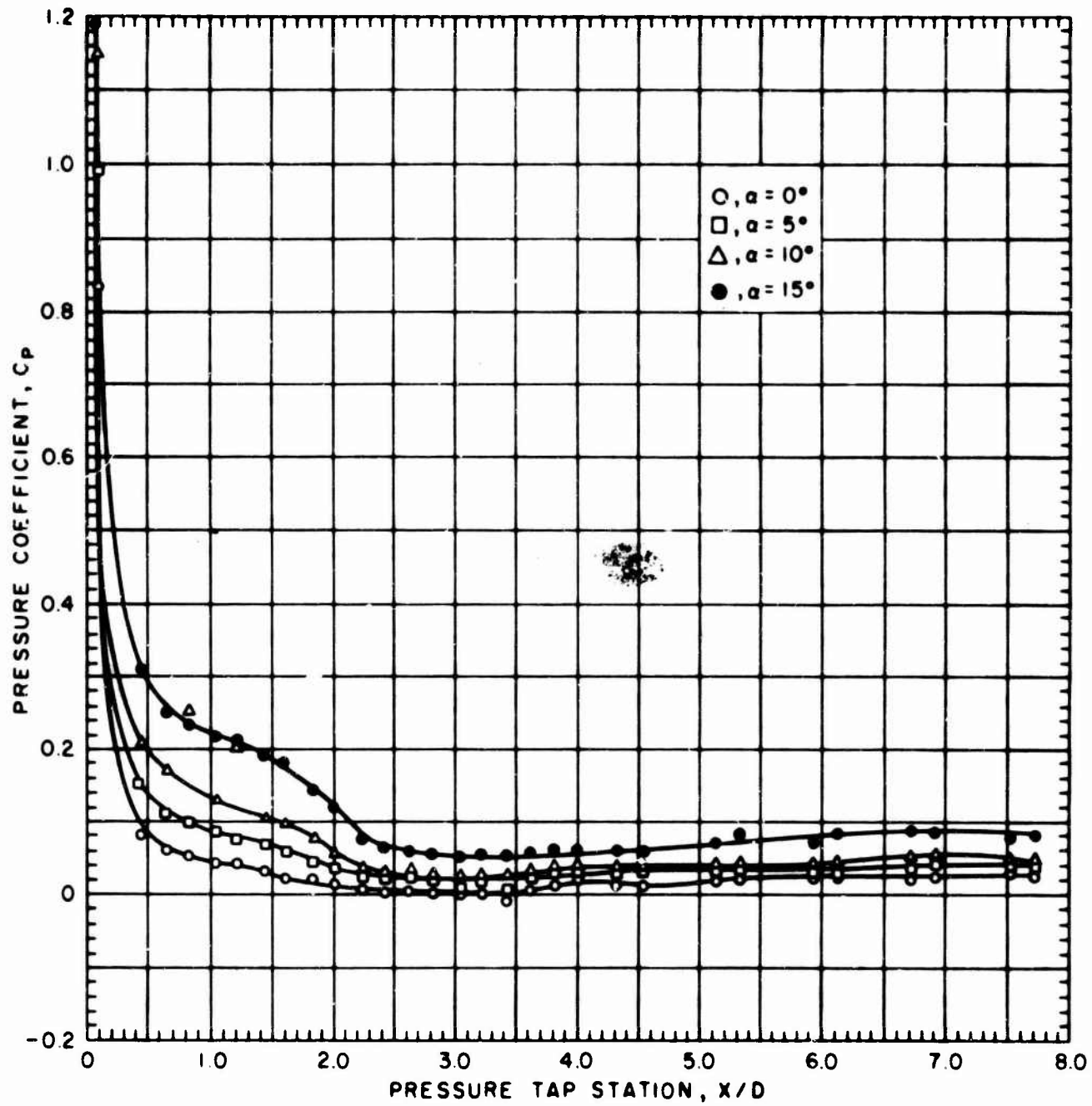
FIG. 7.   Longitudinal Pressure Distribution (φ = 180 Deg), MIT Data.

A more informative presentation of the circumferential pressure distribution is to plot the data at each station in polar coordinate form. Figure 8 shows the results of plotting one of the pressure tap stations from the MIT data in this manner. The radial scale to which the data are plotted has the zero value at the center of the polar coordinates and is defined as being positive outward. It is quite evident that the data, when presented in this form, appear to have rather erratic excursions in the circumferential pressure distribution. All of the pressure coefficient data plotted in this form tended to have the same kind of data, but to differing degrees.

As the MIT wind-tunnel tests were conducted first, the data obtained were plotted in the manner just described, and the resultant curves led to some suspicion that there might have been some characteristics of the hot core wind tunnel which could have produced such apparently erratic results. This possibility was checked by testing the same model in a different facility (in this case at Pt. Mugu) at as close to the original test conditions as could be obtained on short notice. In addition, this opportunity was used to obtain data at closer intervals around the circumference.

The data from the Pt. Mugu tests were plotted in the same manner as the MIT data. Examples of the resultant curves in both Cartesian coordinate and polar coordinate forms are shown in Fig. 9-13. It can easily be inferred from the behavior of the polar curves that the unexpected excursions were not the exclusive property of the MIT data and that the MIT wind tunnel was not at fault.

Elimination of the wind tunnel as the source of the strangely behaving polar curves leads immediately to the question of whether or not the flow over the body of revolution could have produced such unusual pressure fields. This possibility is always present since the flow on long slender bodies shows it is conducive to vortex generation, with resultant effect upon the local pressures and flow velocities (Ref. 5).

In the present case, the solution to the question of the unusually shaped curves is much less exotic than an explanation involving vortex trails and pressure fields. Figure 14 shows the same data as that used in Fig. 8, plotted again in polar coordinate form, but this time with the zero pressure coefficient scale located outward on one of the circles rather than at the center of the polar presentation. The curves obtained with this new polar-scaling show a much more regular behavior than those in Fig. 8. It is obvious that the method of assigning the scales to the polar coordinates was responsible for much of the irregularity of the curves shown in Fig. 8.

FIG. 8. Polar Plot With Zero C_p Located at Center, MIT Data.
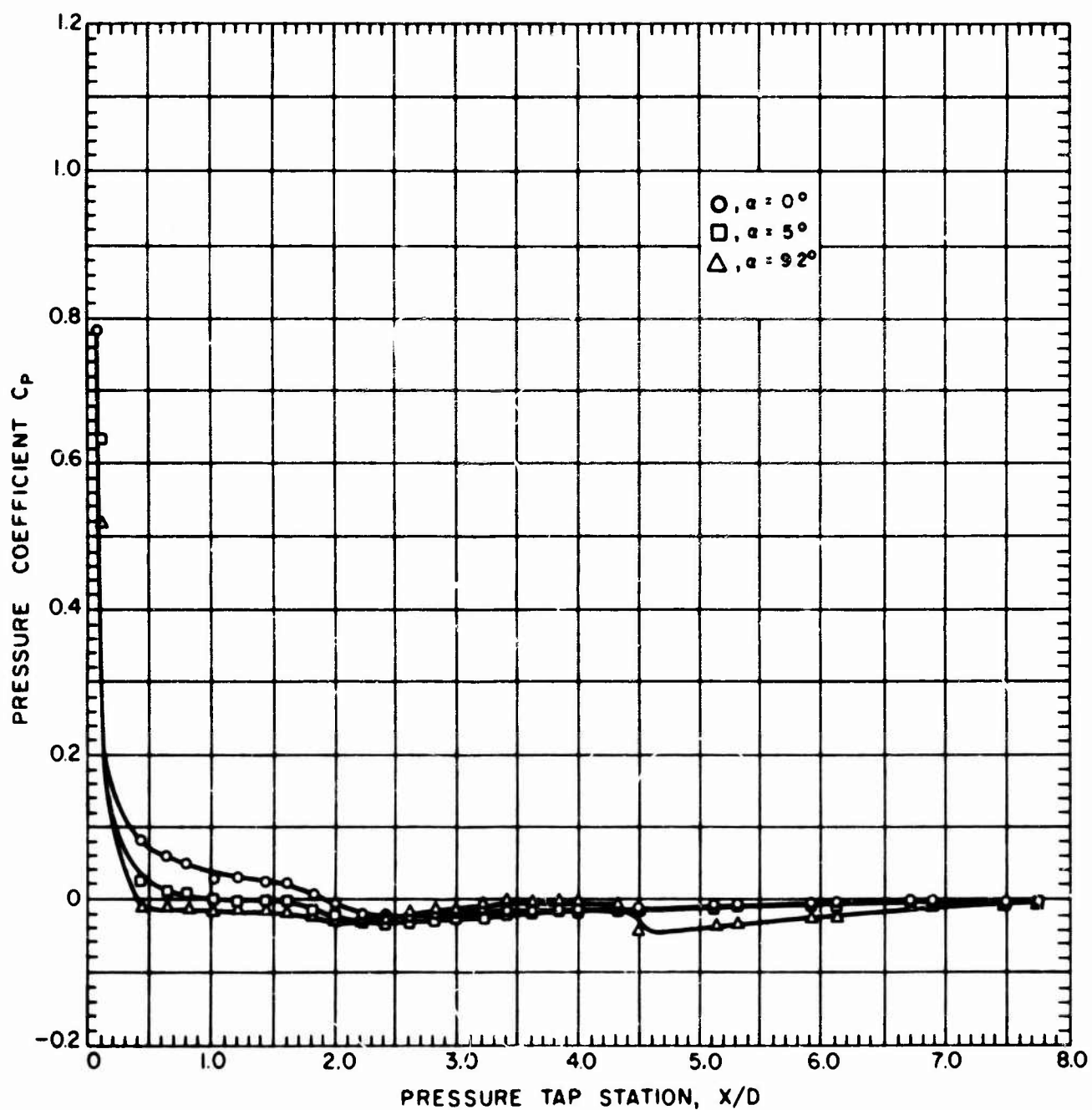
FIG. 9. Longitudinal Pressure Distribution (φ = 0 Deg),
Pt. Mugu Data.
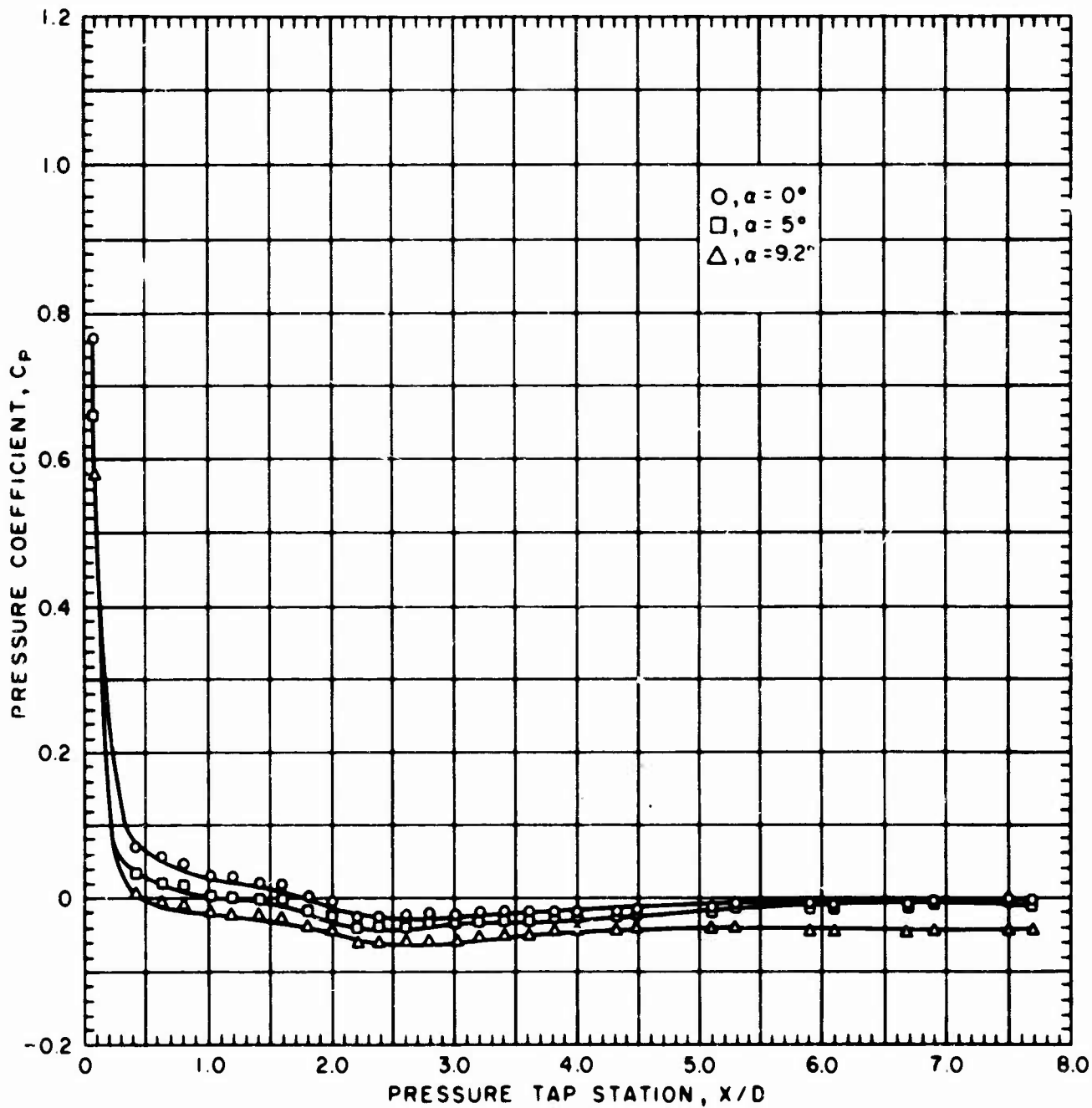
FIG. 10. Longitudinal Pressure Distribution (φ = 45 Deg), Pt. Mugu Data.
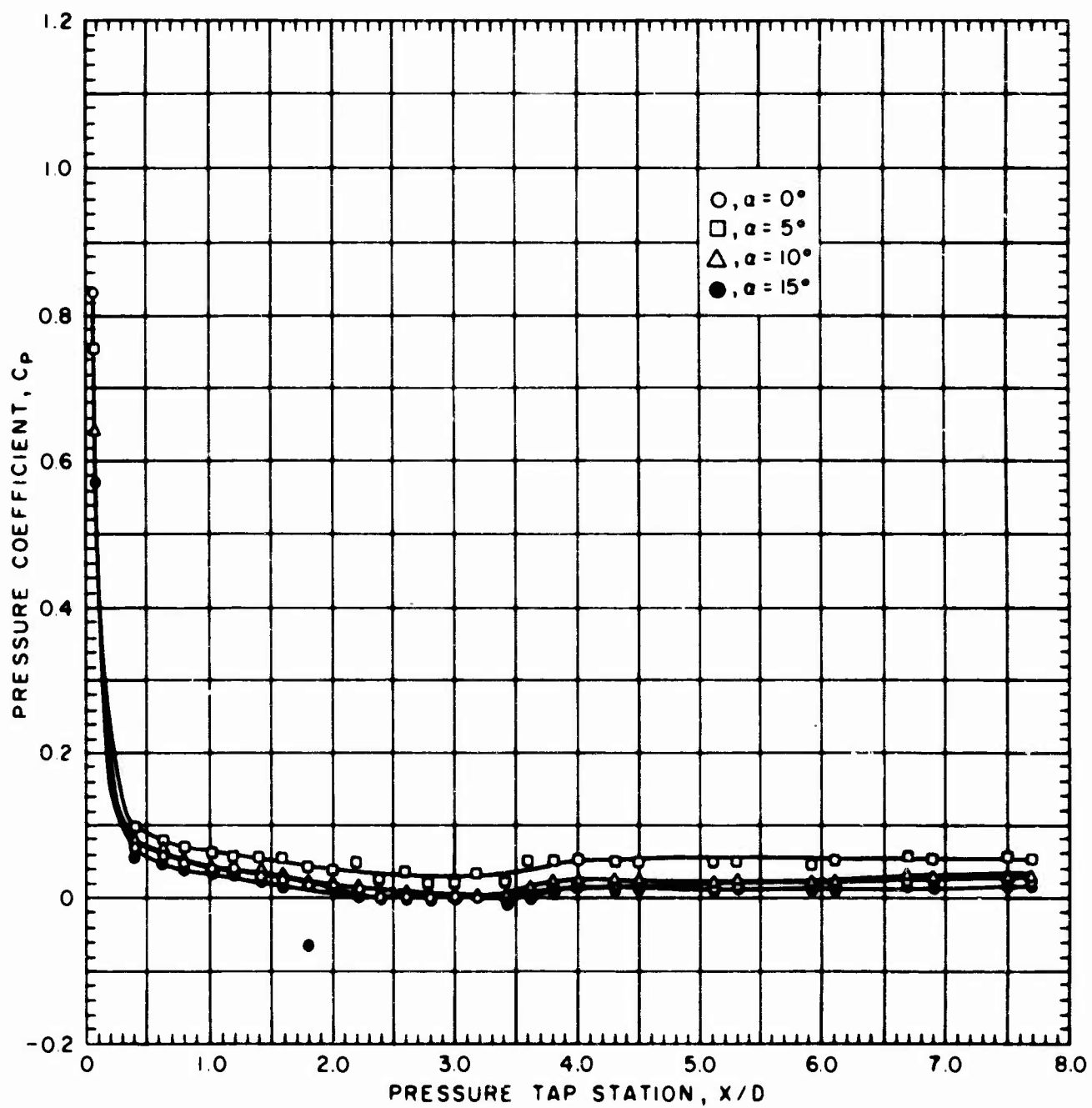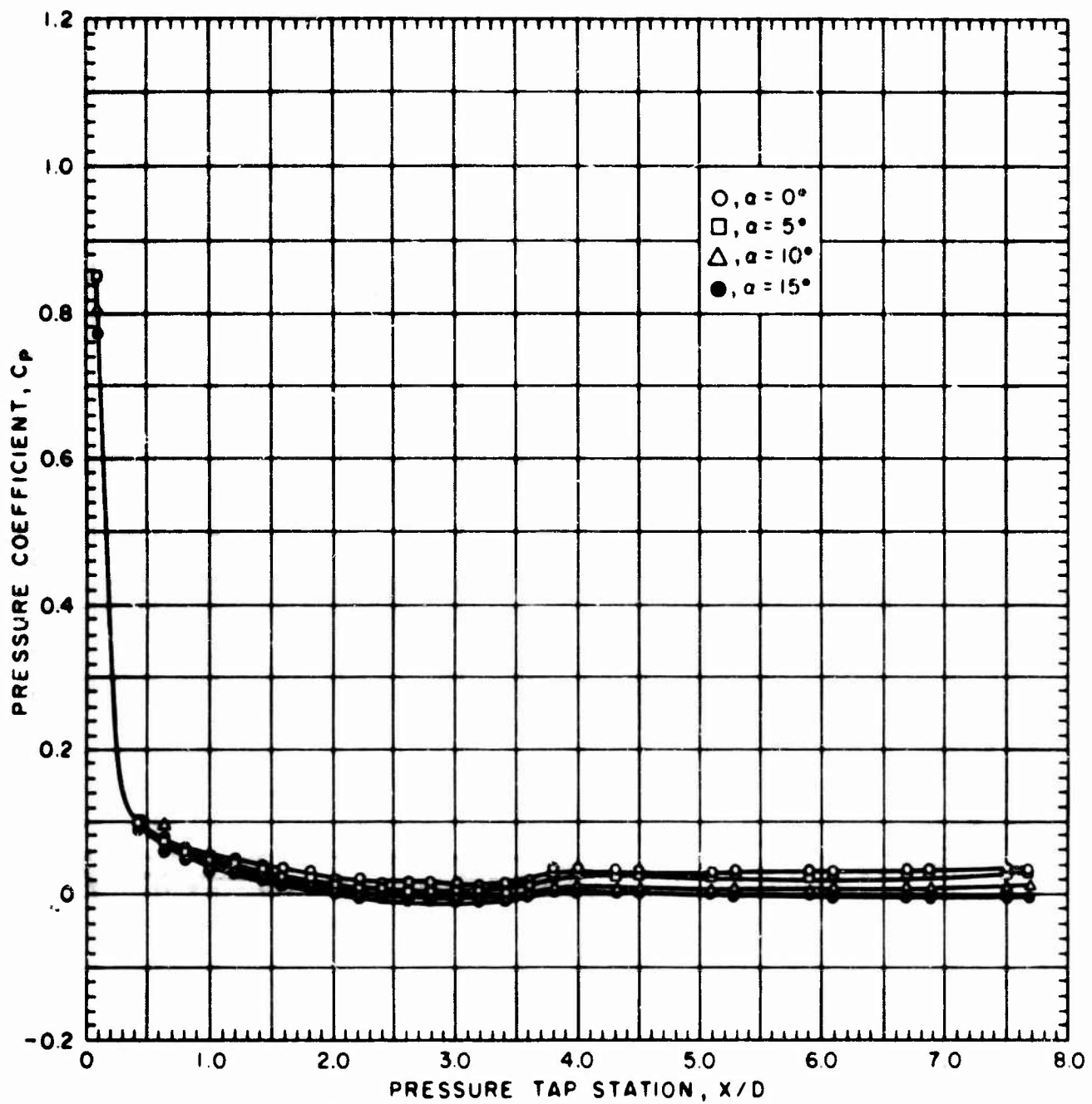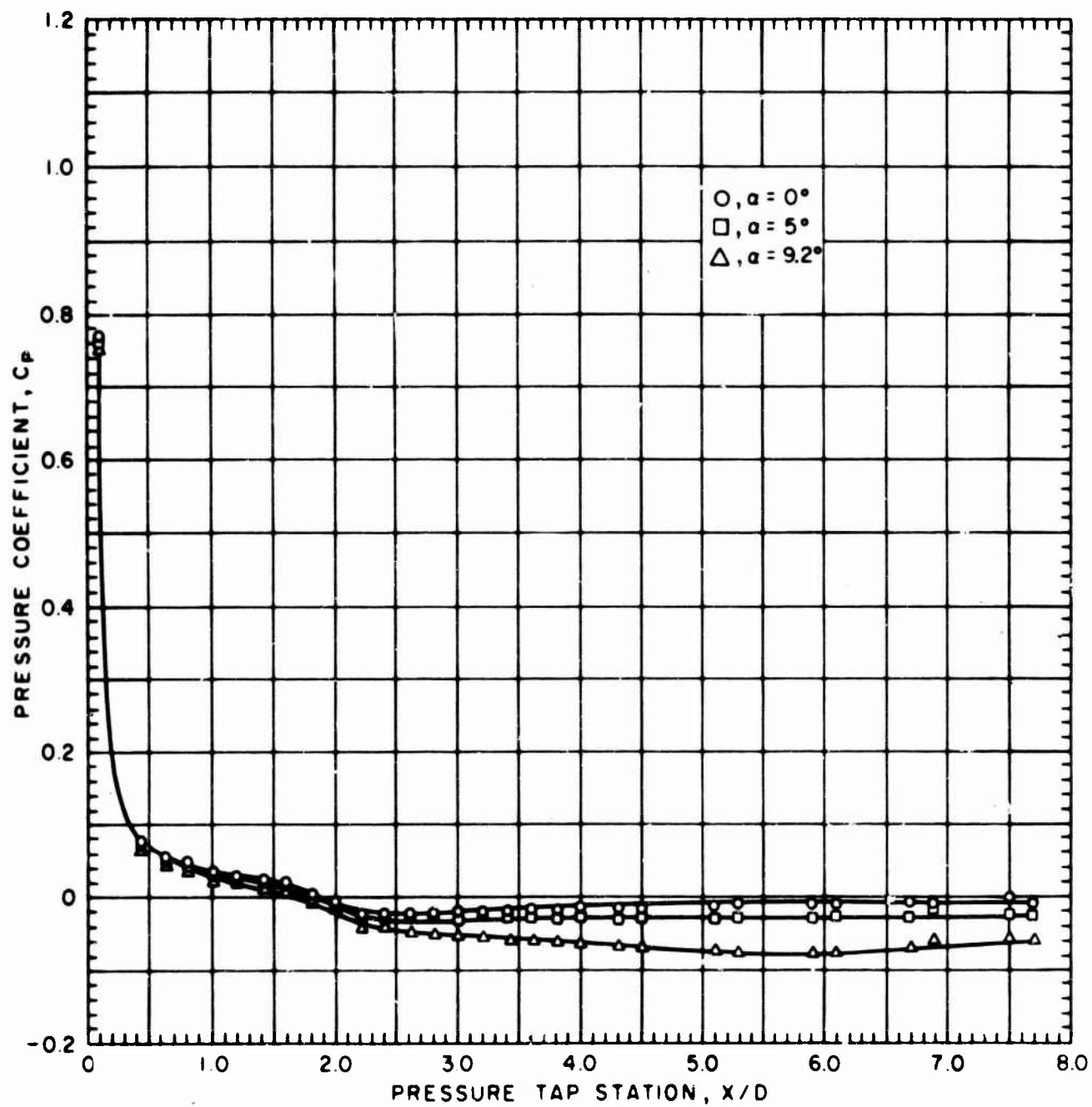
FIG. 11. Longitudinal Pressure Distribution (φ = 90 Deg),
Pt. Mugu Data.

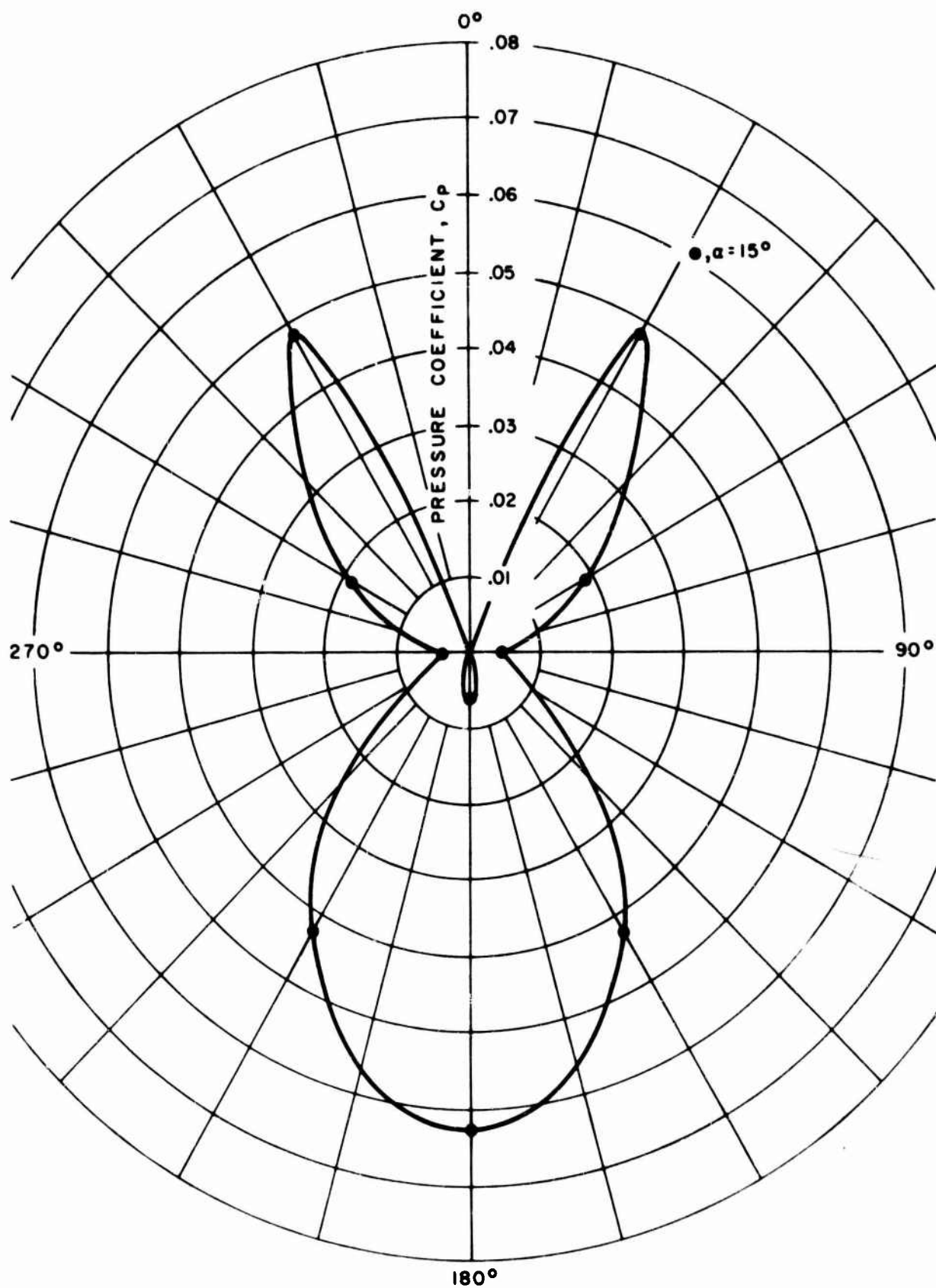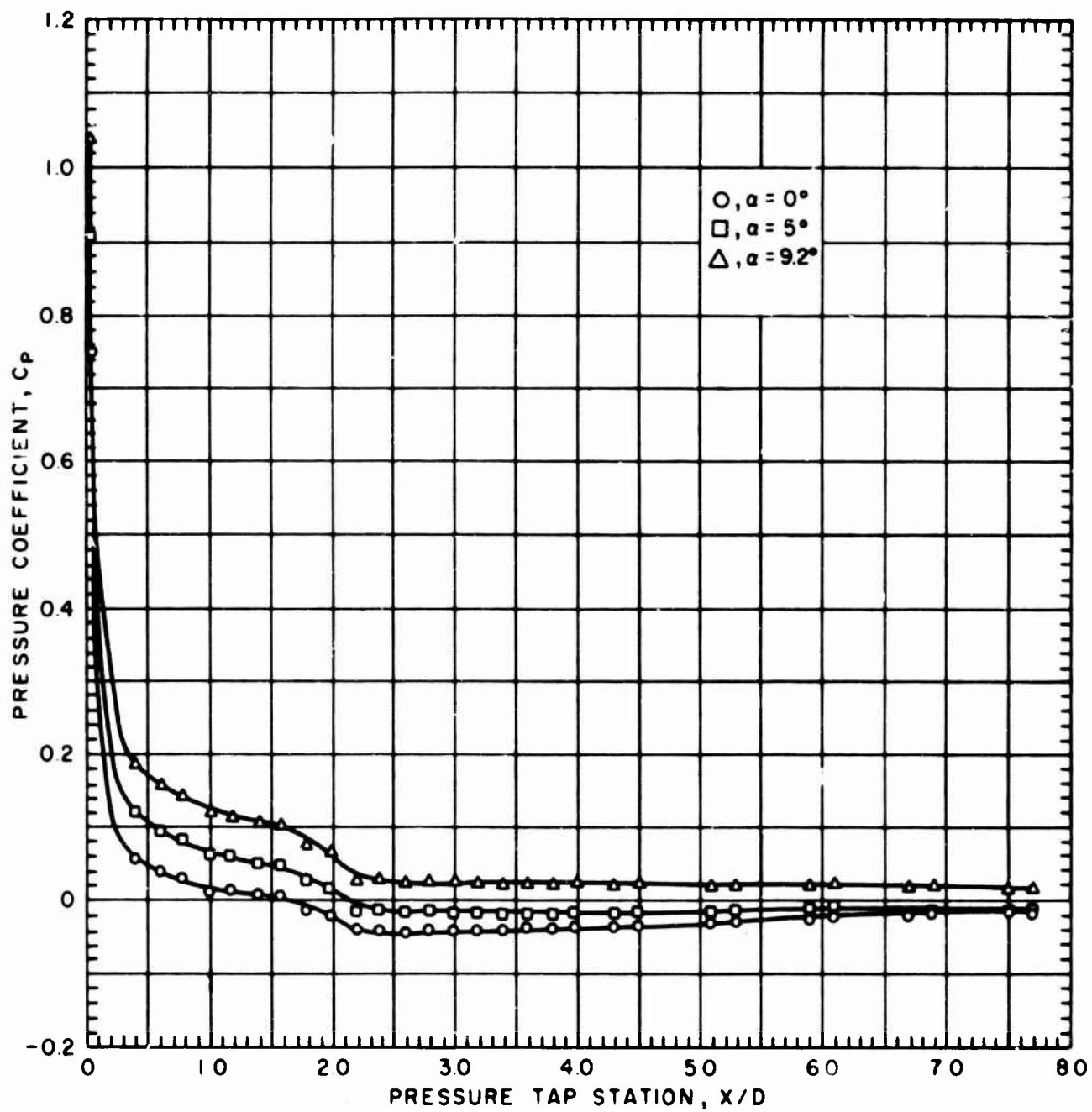FIG. 12.   Longitudinal Pressure Distribution (φ = 180 Deg),
Pt. Mugu Data.
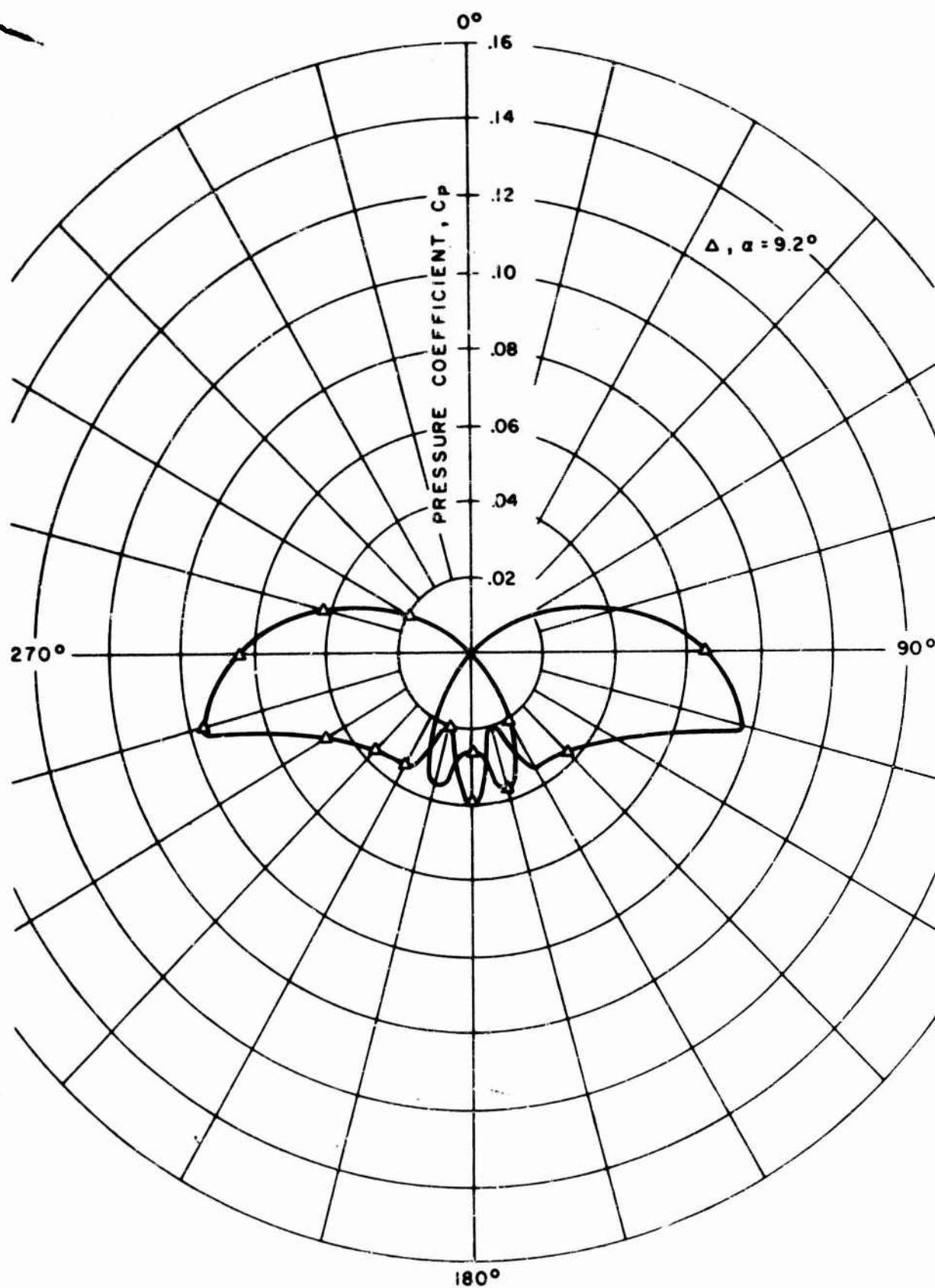
FIG. 13. Polar Plot With Zero C_p Located at Center, Pt. Mugu Data.
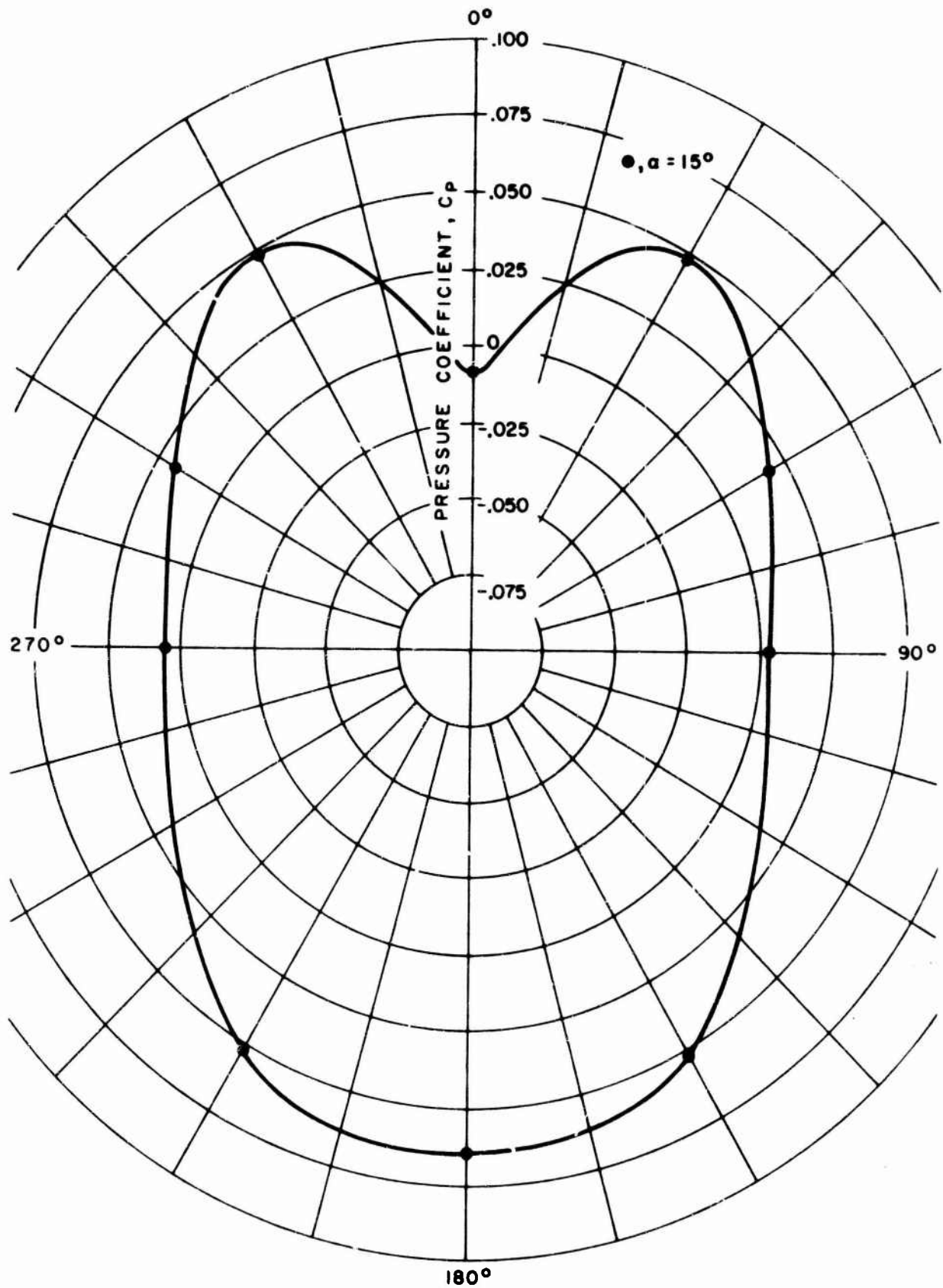
FIG. 14. Polar Plot With Zero C_p Displaced From
Center, MIT Data.

Figures 15-36 show the data obtained in both the MIT and Pt. Mugu tests, plotted with the new scaling. The curves are presented for selected pressure tap stations to keep the number of graphs to a reasonable total. A complete series of tables of the reduced wind-tunnel pressure data for the two test programs is presented in Appendix B and C.

Each of the circumferential pressure distribution curves in Fig. 15-36 has certain common features. The most evident feature is that the curves all show an increase in the magnitude of the pressure coefficients on the windward side of the body as the angle of attack is increased, an effect which could be intuitively expected. Also, if the crossflow and viscous effects are ignored, the curves all tend to have a circular pattern for those pressure tap stations located downstream on the cylindrical portion of the body.

Considering the MIT data for the higher angles of attack (10 and 15 degrees) at stations on the cylindrical region of the body (Fig. 15-25), each circumferential pressure-distribution curve shows that the pressure is relatively lower at the sides than either the top or bottom, the bottom being defined as the windward side of the body. This region of lower pressure can be attributed to the increase in the crossflow velocity component at the sides due to the angle of attack. Aside from the significantly lower pressures registered on the body top at $\varphi = 0$ degree, which probably are due to some error either in the data or in the instrumentation, there is little variation from the very slight hourglass shape evident in the plotted data.

The circumferential pressure distributions at the downstream stations measured at the Pt. Mugu tests show a marked difference from those of the MIT data, as the hourglass shape is much more pronounced. The reason for these differences undoubtedly arises from the different test conditions since the two Mach numbers were 3.06 and 3.65, and the Reynolds numbers were approximately 8×10^6 and 0.2×10^6 per foot for the MIT and Pt. Mugu wind tunnels, respectively. Since the circumferential pressure distribution is sensitive to viscosity, the differences in the Reynolds numbers obviously had a great effect upon the shapes of the curves. By comparison of the data from the two wind tunnels, it can be concluded that the high Reynolds number flow significantly affects the circumferential pressure distribution on a cylindrical body of revolution at angle of attack.

It may be noted in Fig. 35 and 36, which are the Pt. Mugu data polar plots for the pressure tap stations on the rear portion of the cylindrical body, that the circumferential distribution near the 180-degree region does not conform to the generally smooth figure-eight shape exhibited by the curves for the forward pressure tap stations. Consideration of the material presented in Ref. 6 leads to the observation that the variations from the smooth figure-eight curve of the
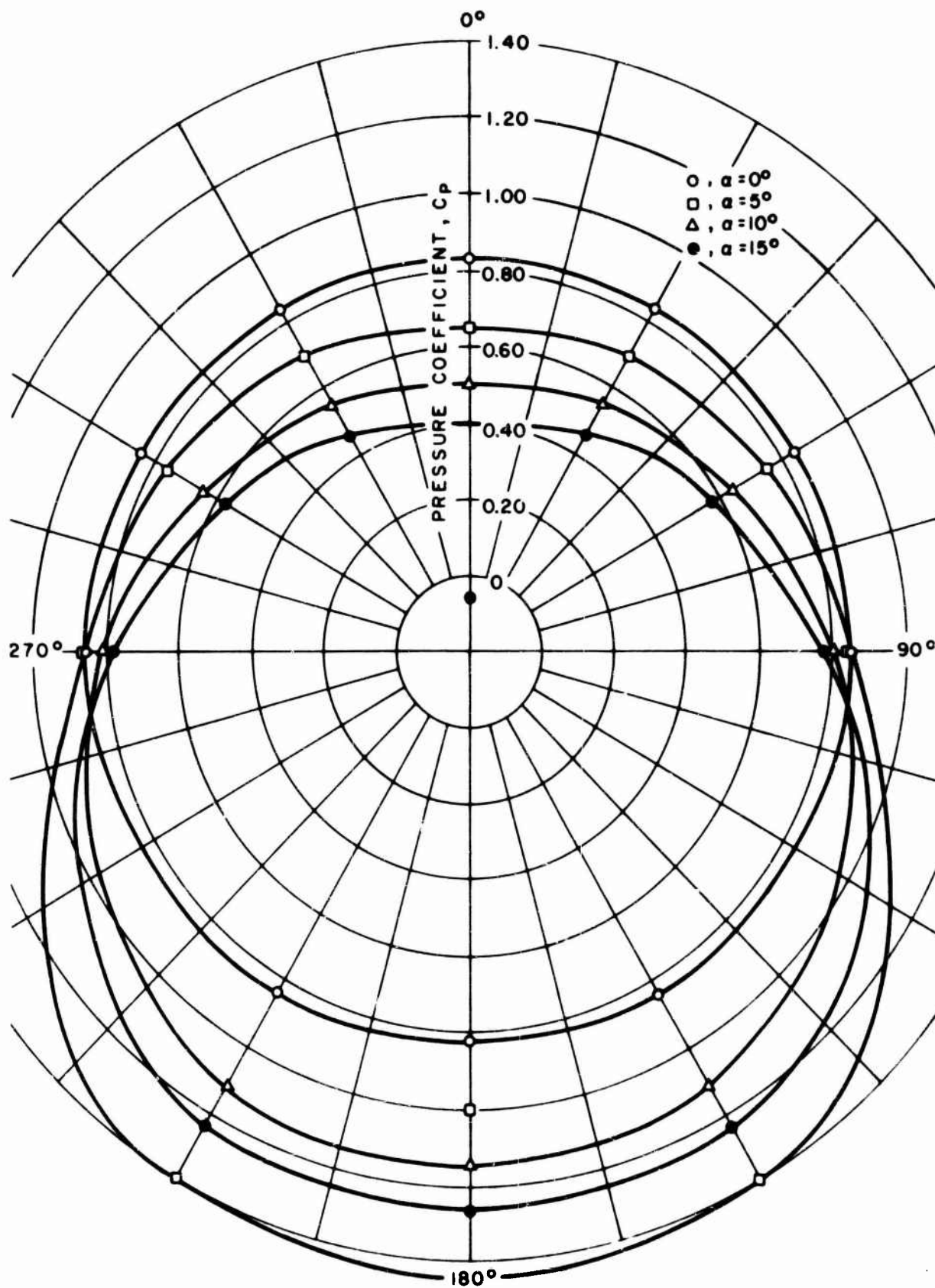
FIG. 15. Pressure Coefficient Polar Coordinates for
Pressure Tap No. 1, MIT Data.
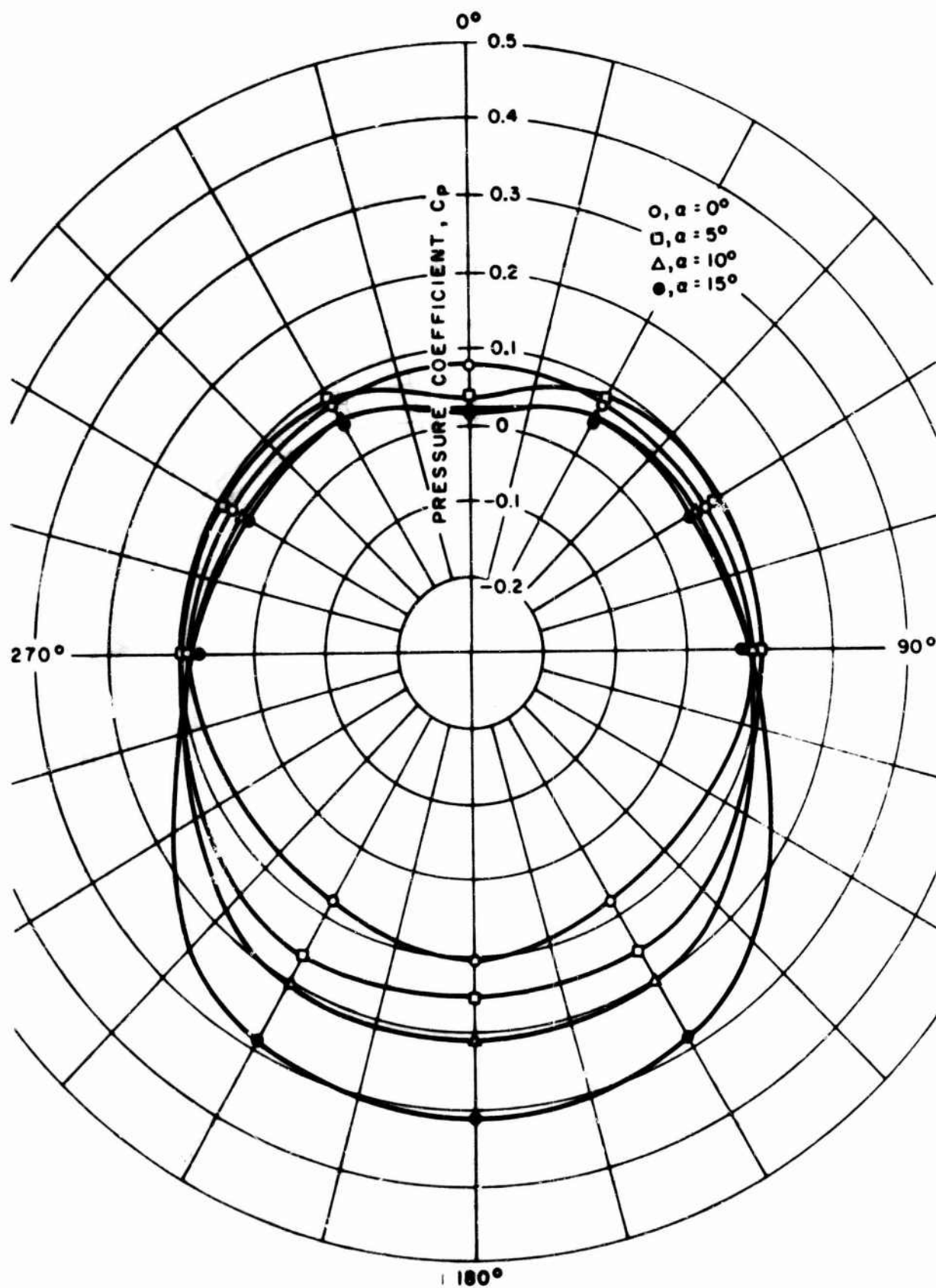
FIG. 16. Pressure Coefficient Polar Coordinates for
Pressure Tap No. 2, MIT Data.
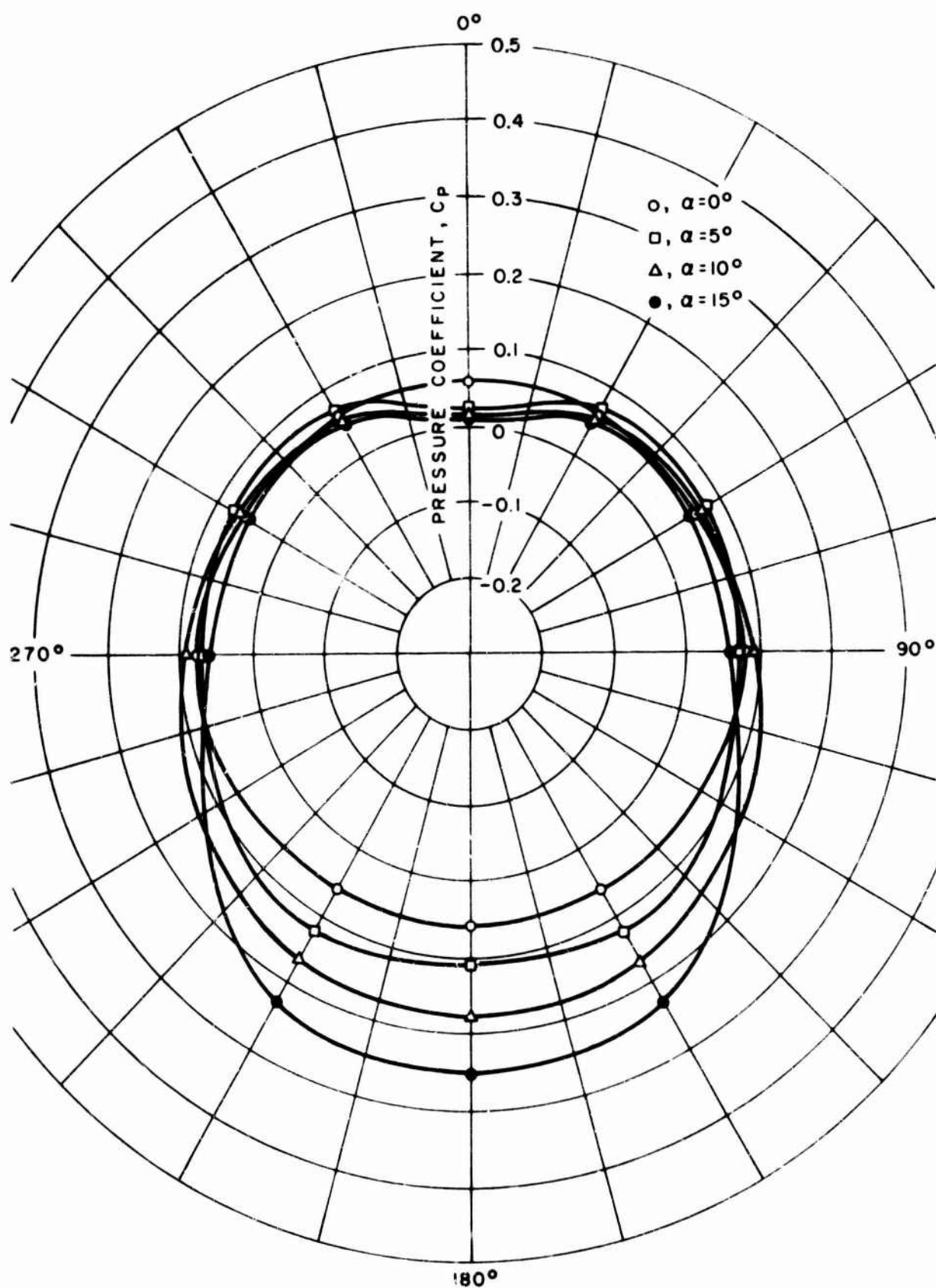
FIG. 17. Pressure Coefficient Polar Coordinates for
Pressure Tap No. 3, MIT Data.

FIG. 18. Pressure Coefficient Polar Coordinates for
Pressure Tap No. 6, MIT Data.
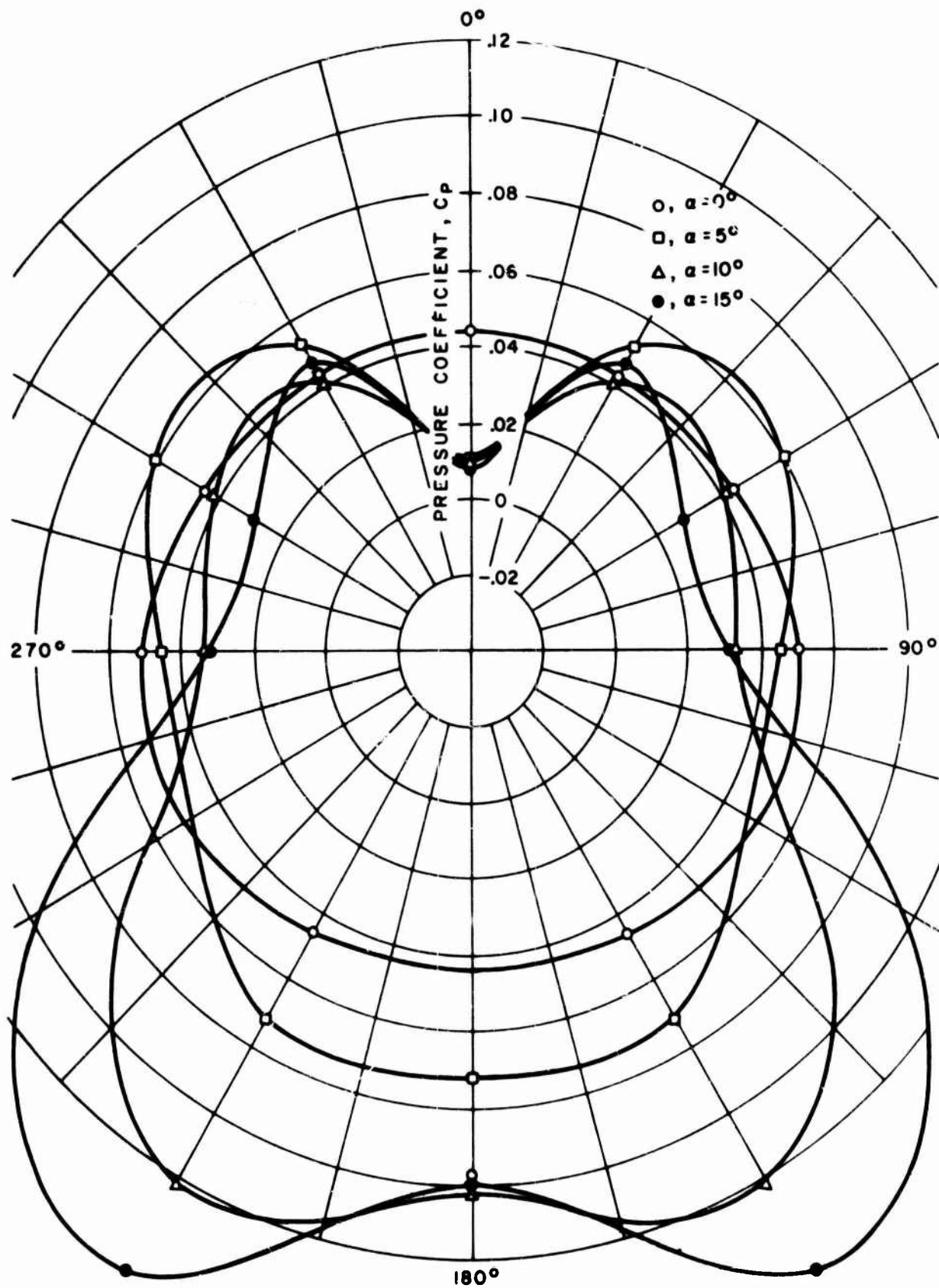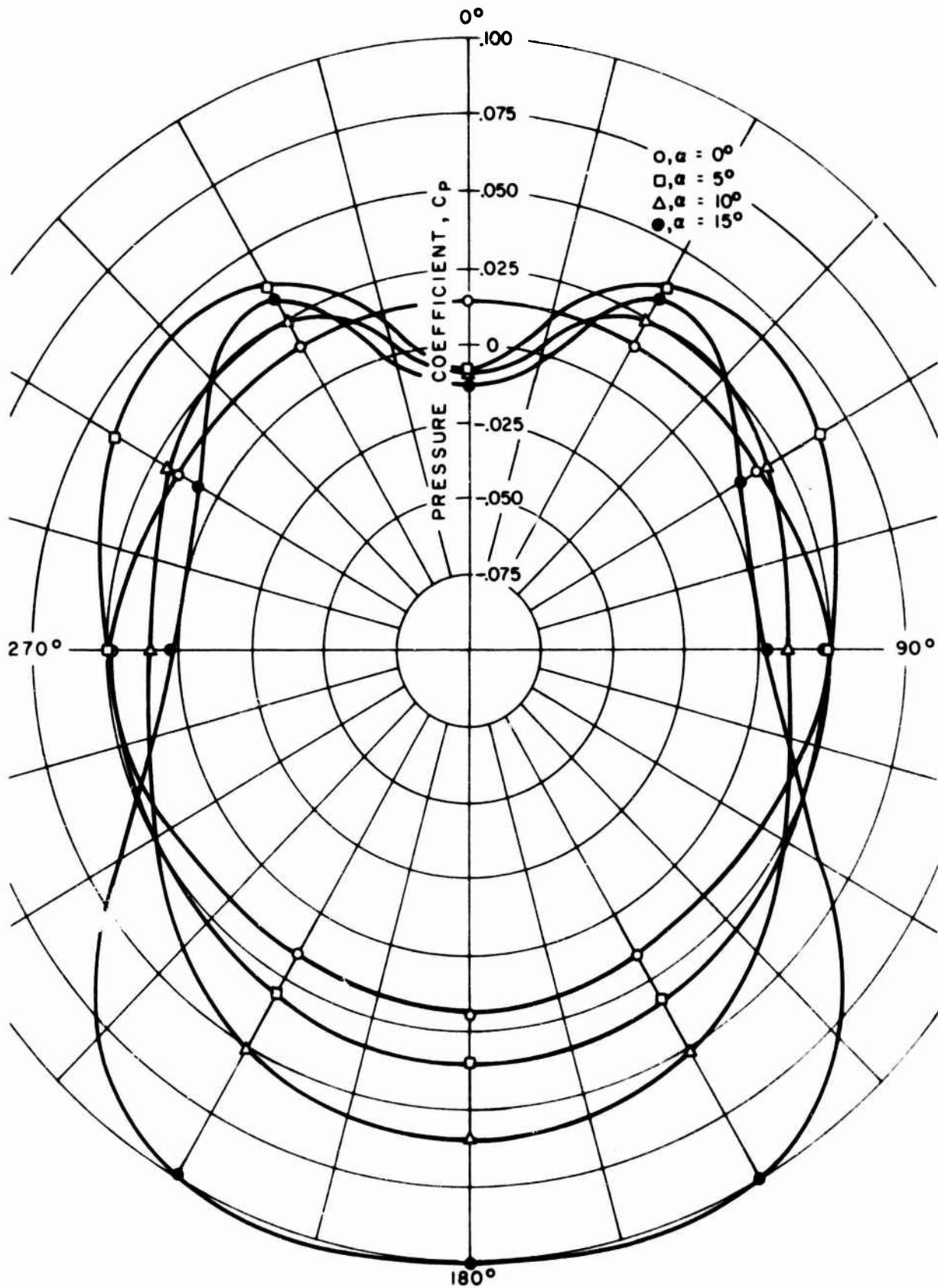
FIG. 19. Pressure Coefficients Polar Coordinates for
Pressure Tap No. 10, MIT Data.
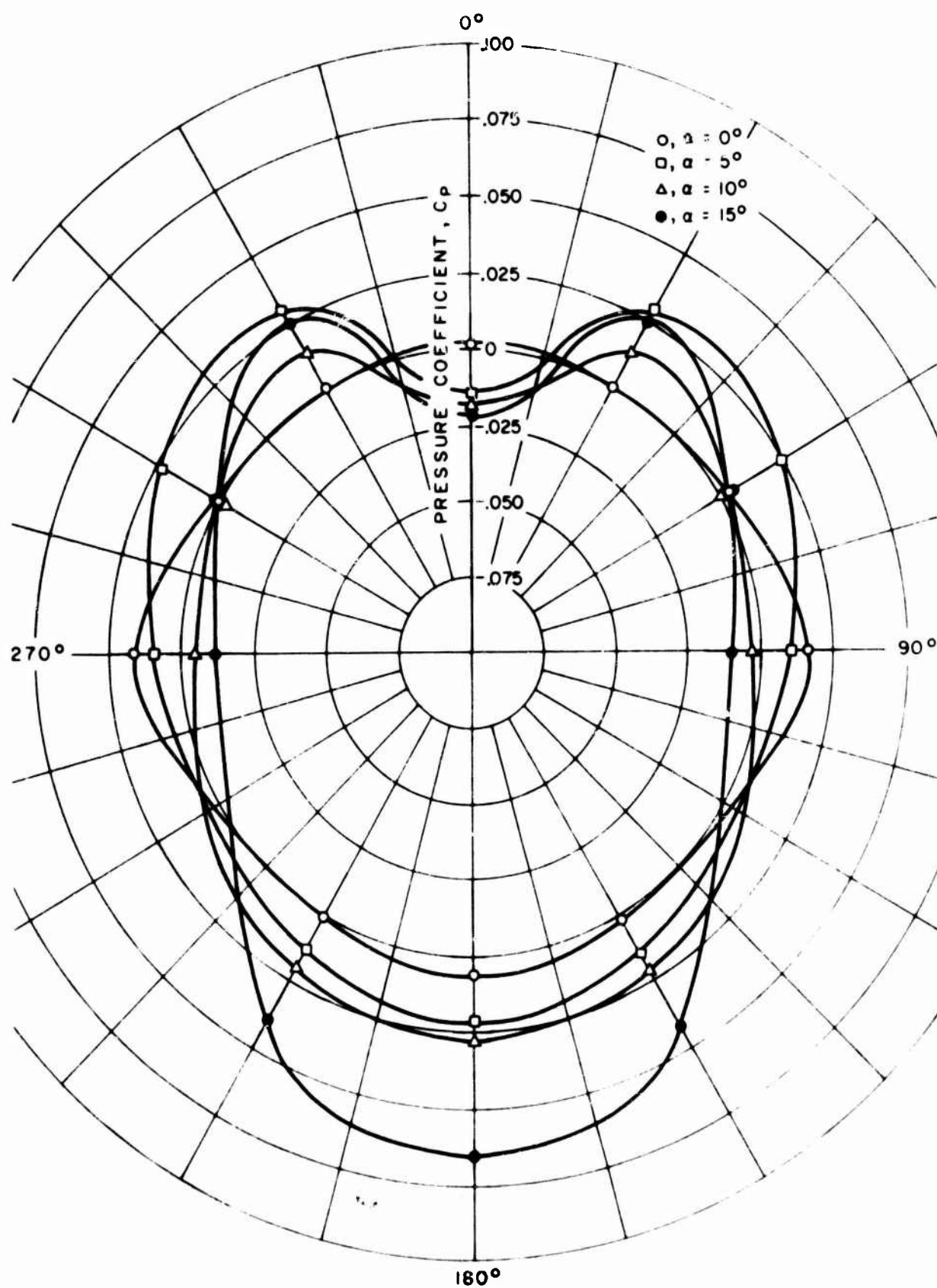
FIG. 20. Pressure Coefficient Polar Coordinates for
Pressure Tap No. 12, MIT Data.
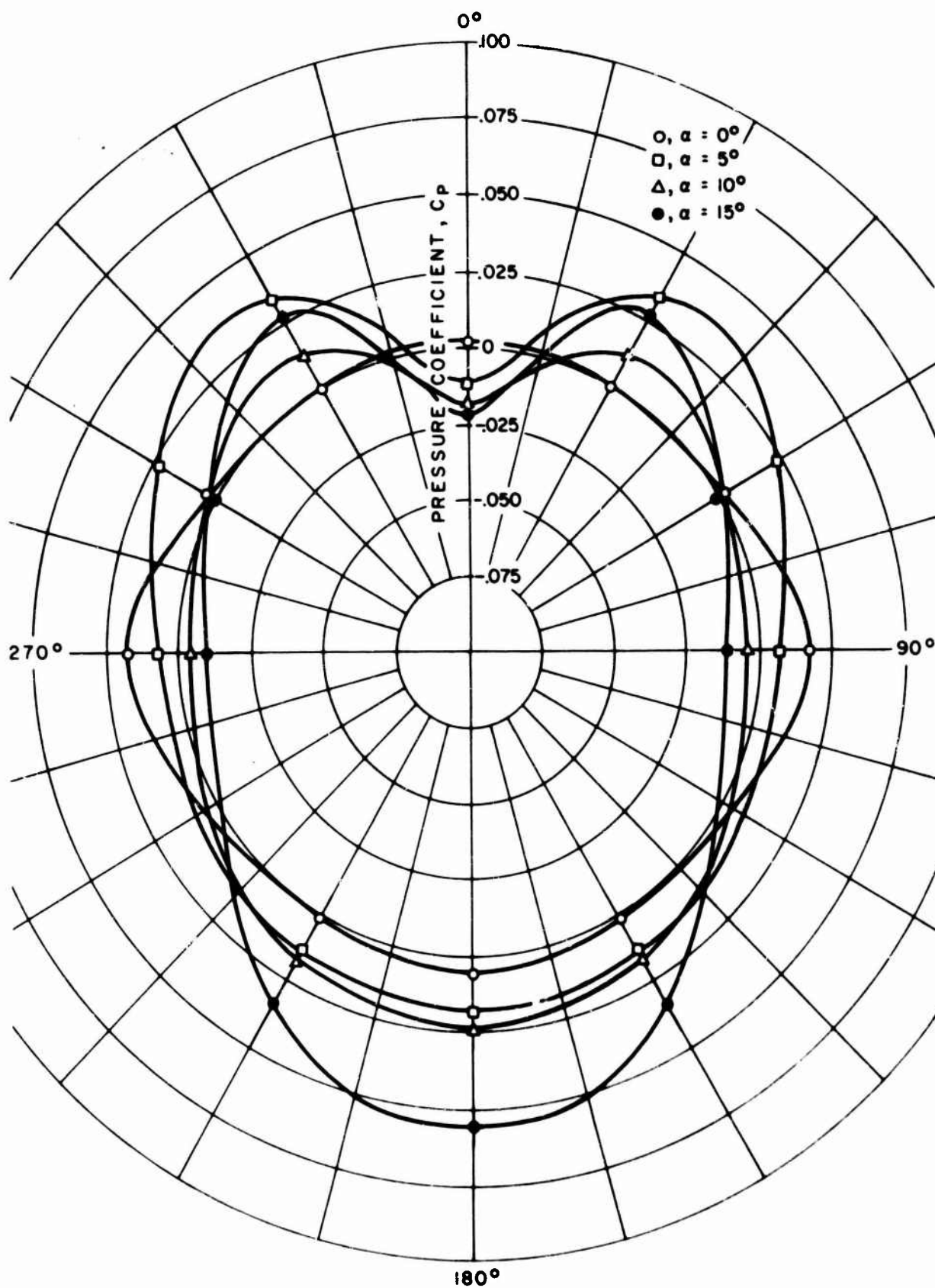
FIG. 21. Pressure Coefficient Polar Coordinates for Pressure Tap No. 14, MIT Data.
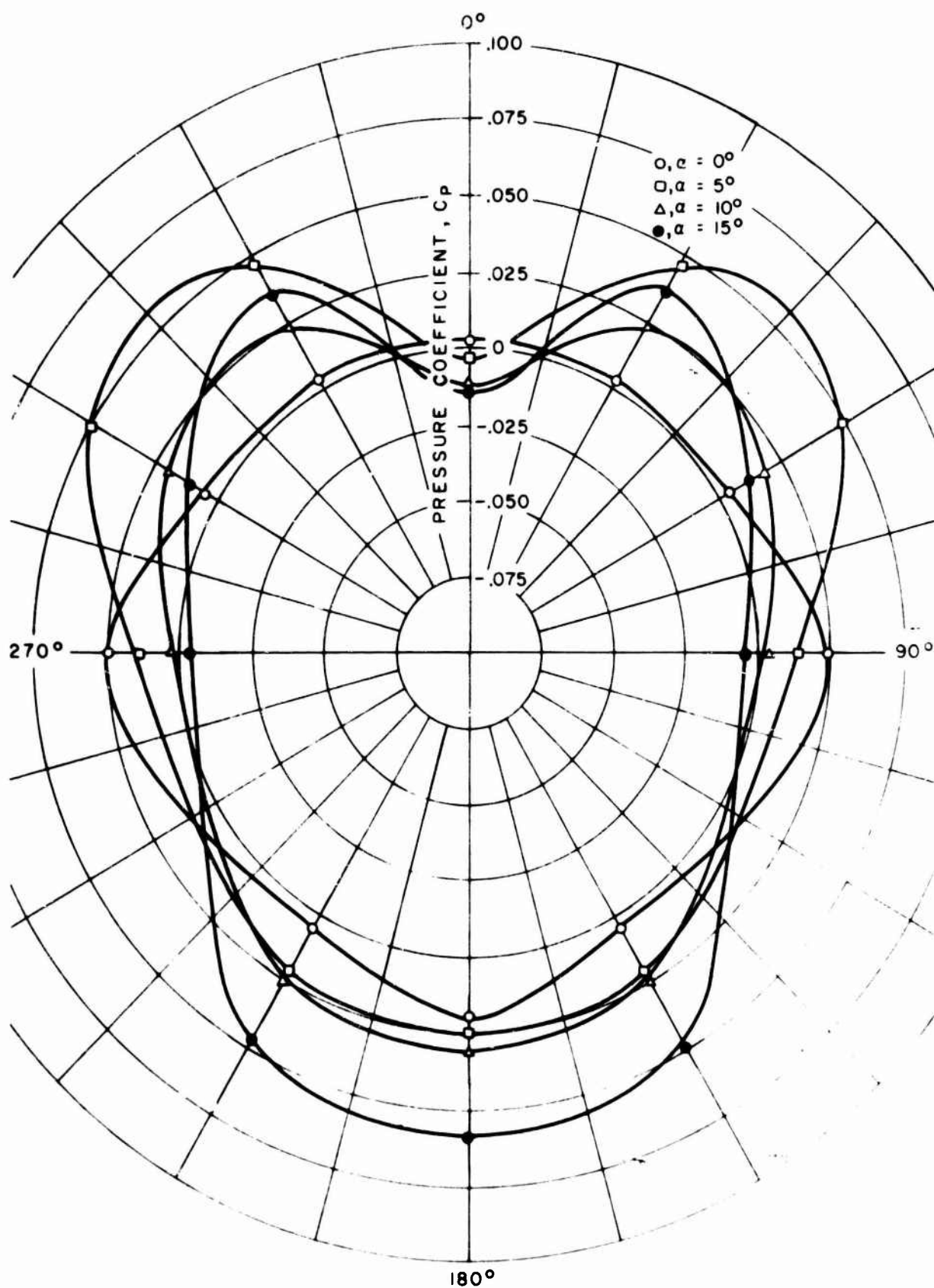
FIG. 22. Pressure Coefficient Polar Coordinates for
Pressure Tap No. 18, MIT Data.
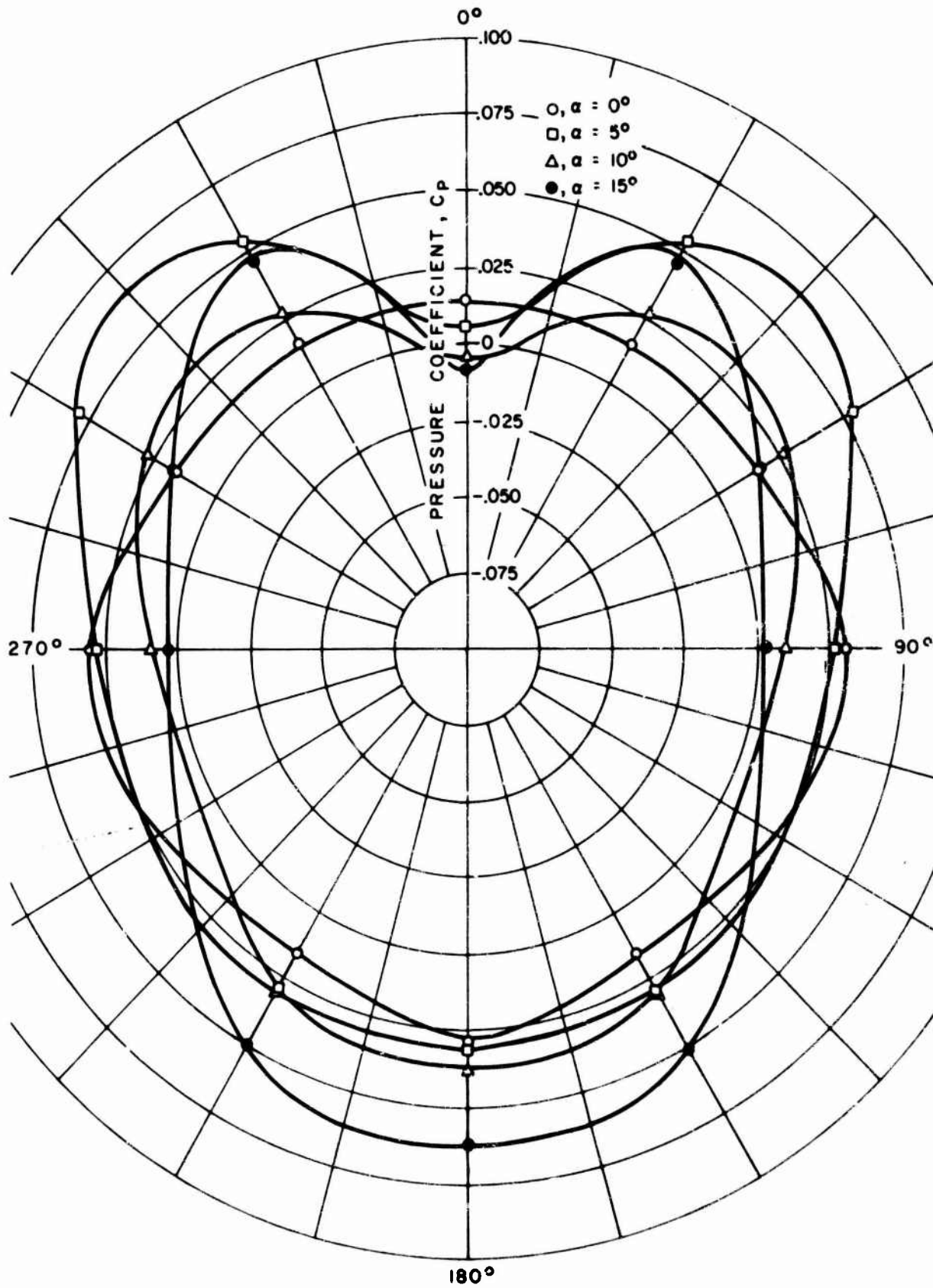
FIG. 23. Pressure Coefficient Polar Coordinates for
Pressure Tap No. 22, MIT Data.
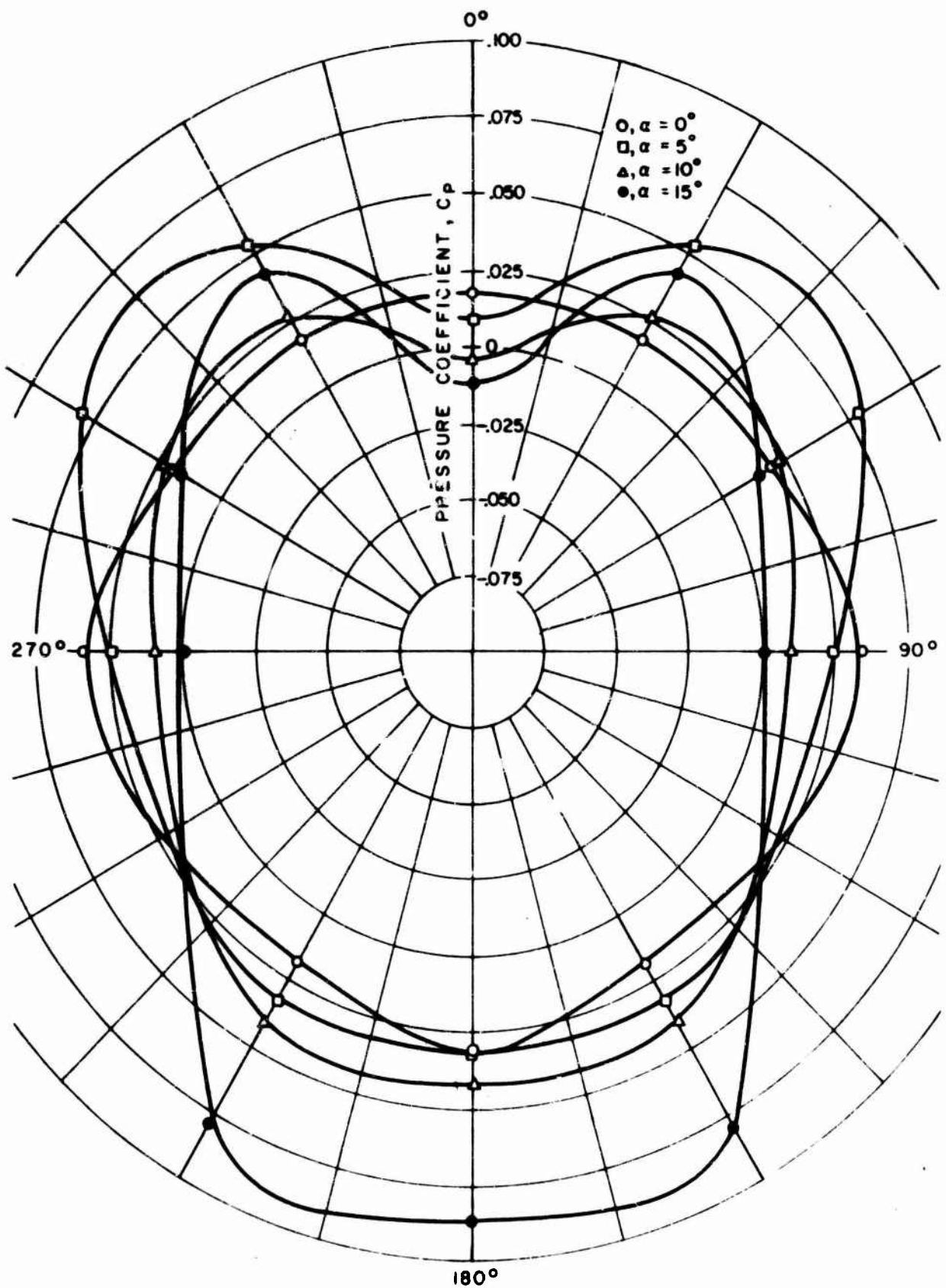
FIG. 24. Pressure Coefficient Polar Coordinates for
Pressure Tap No. 26, MIT Data.
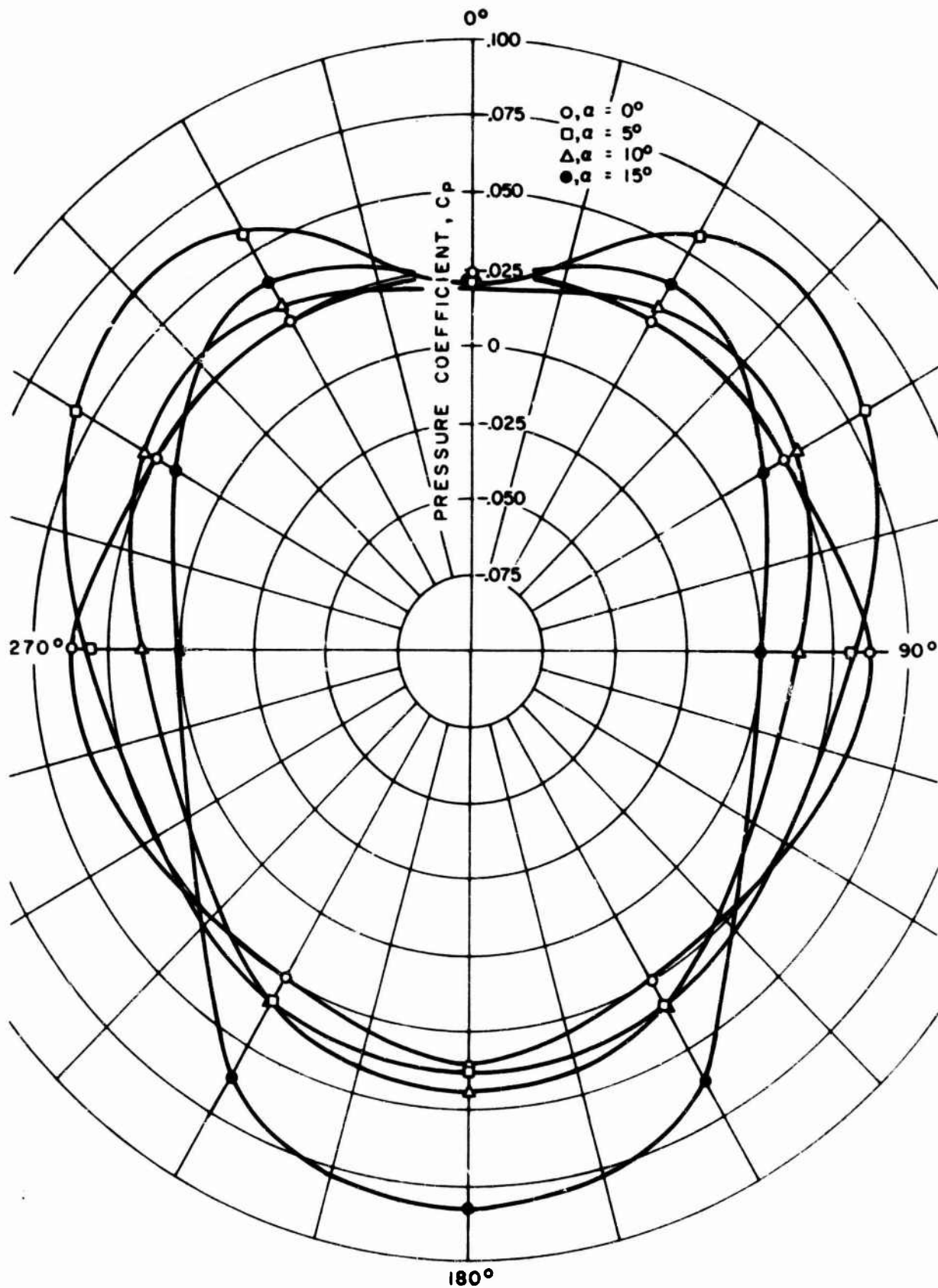
FIG. 25. Pressure Coefficient Polar Coordinates for Pressure Tap No. 30, MIT Data.
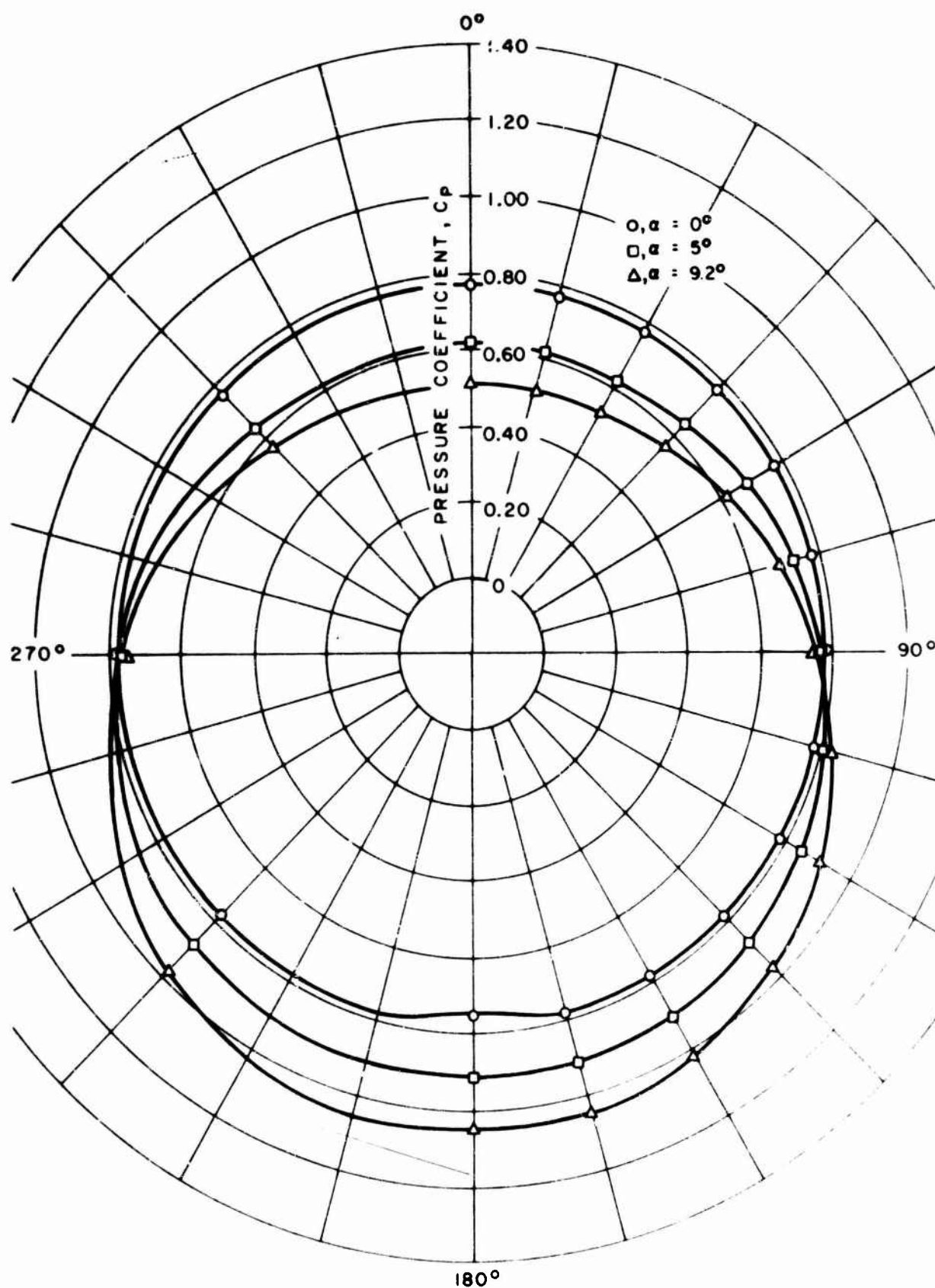
FIG. 26. Pressure Coefficient Polar Coordinates for Pressure Tap No. 1, Pt. Mugu Data.
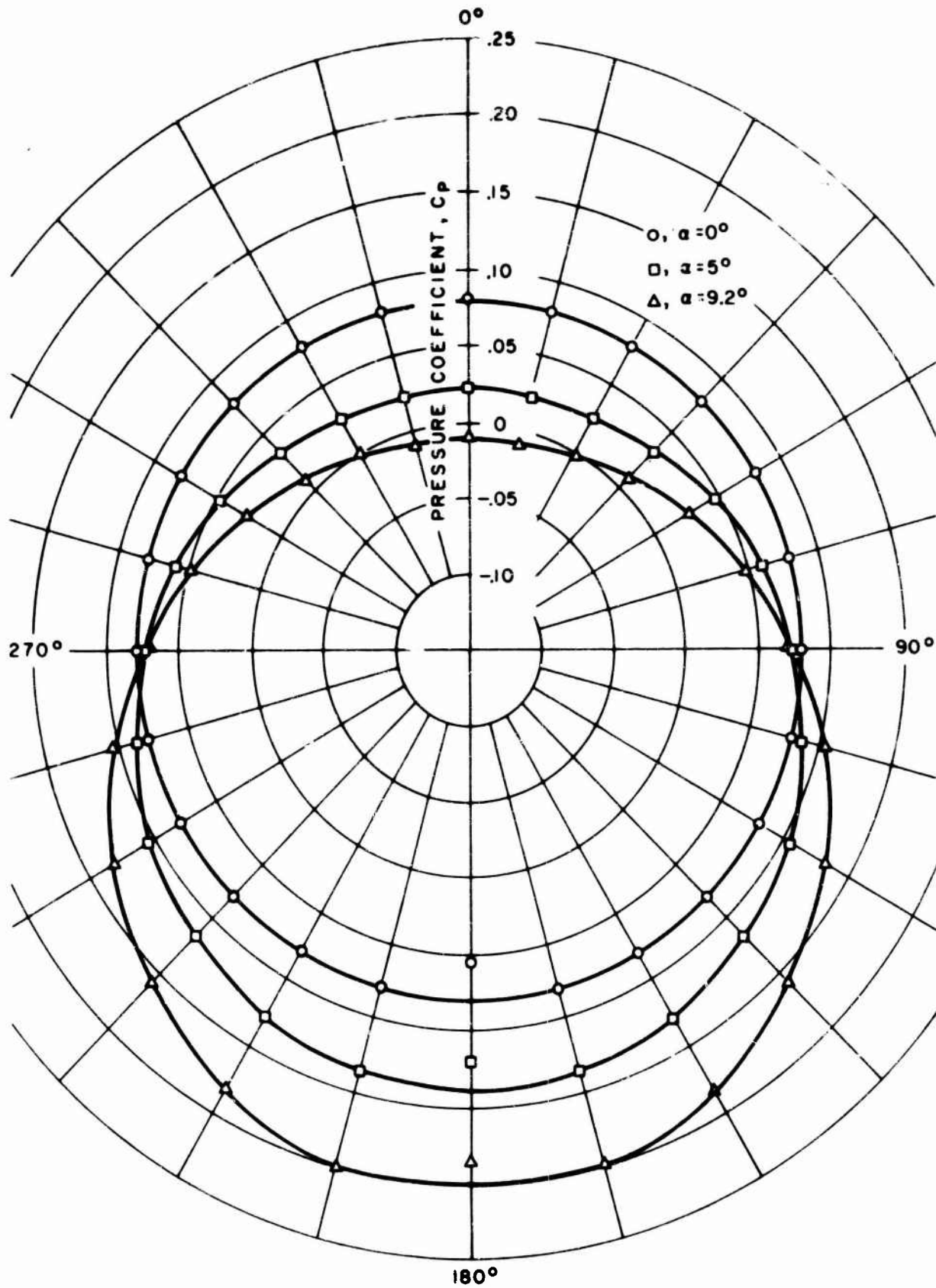
FIG. 27. Pressure Coefficient Polar Coordinates for
Pressure Tap No. 2, Pt. Mugu Data.
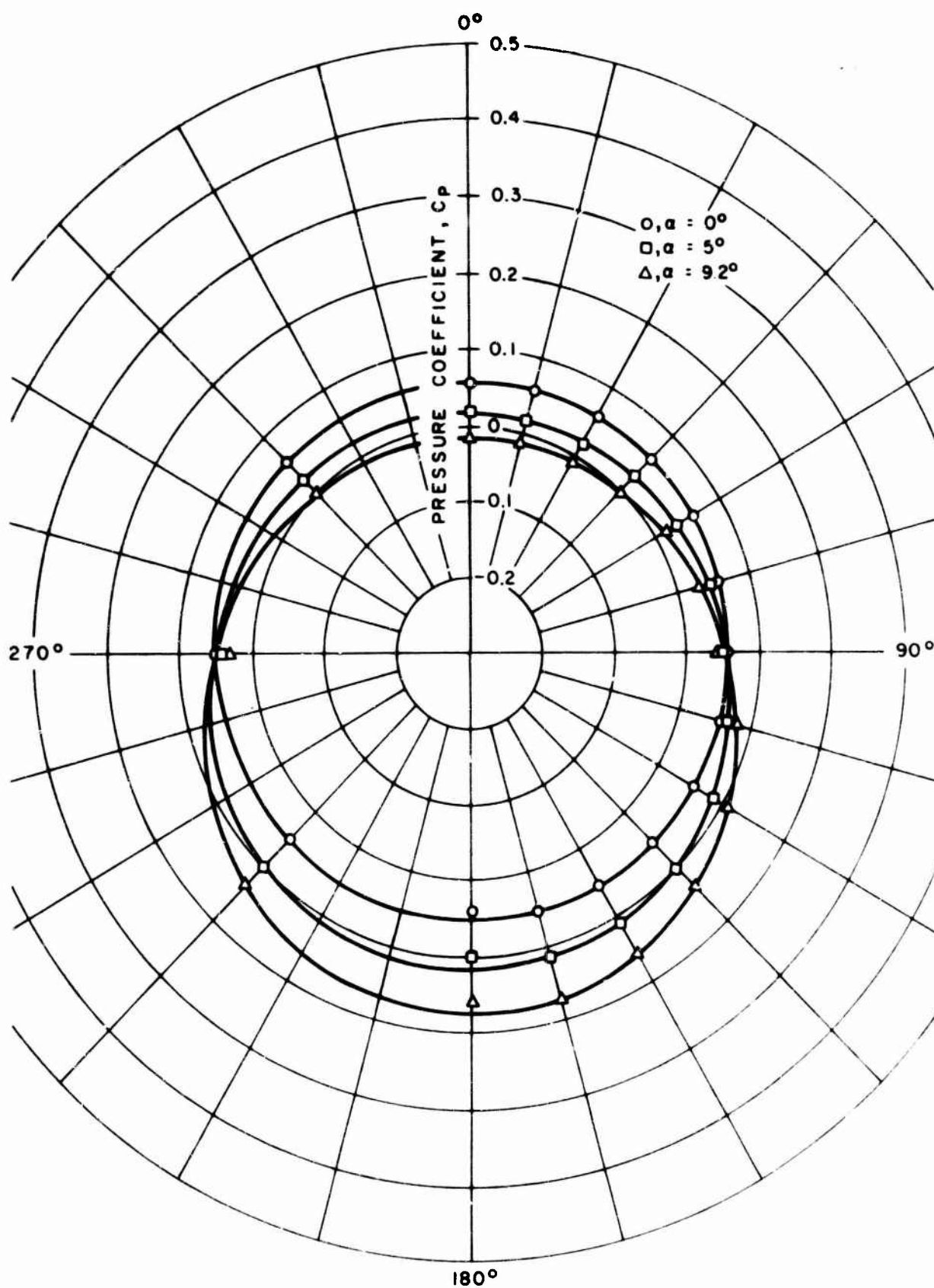
FIG. 28. Pressure Coefficient Polar Coordinates for
Pressure Tap No. 3, Pt. Mugu Data.
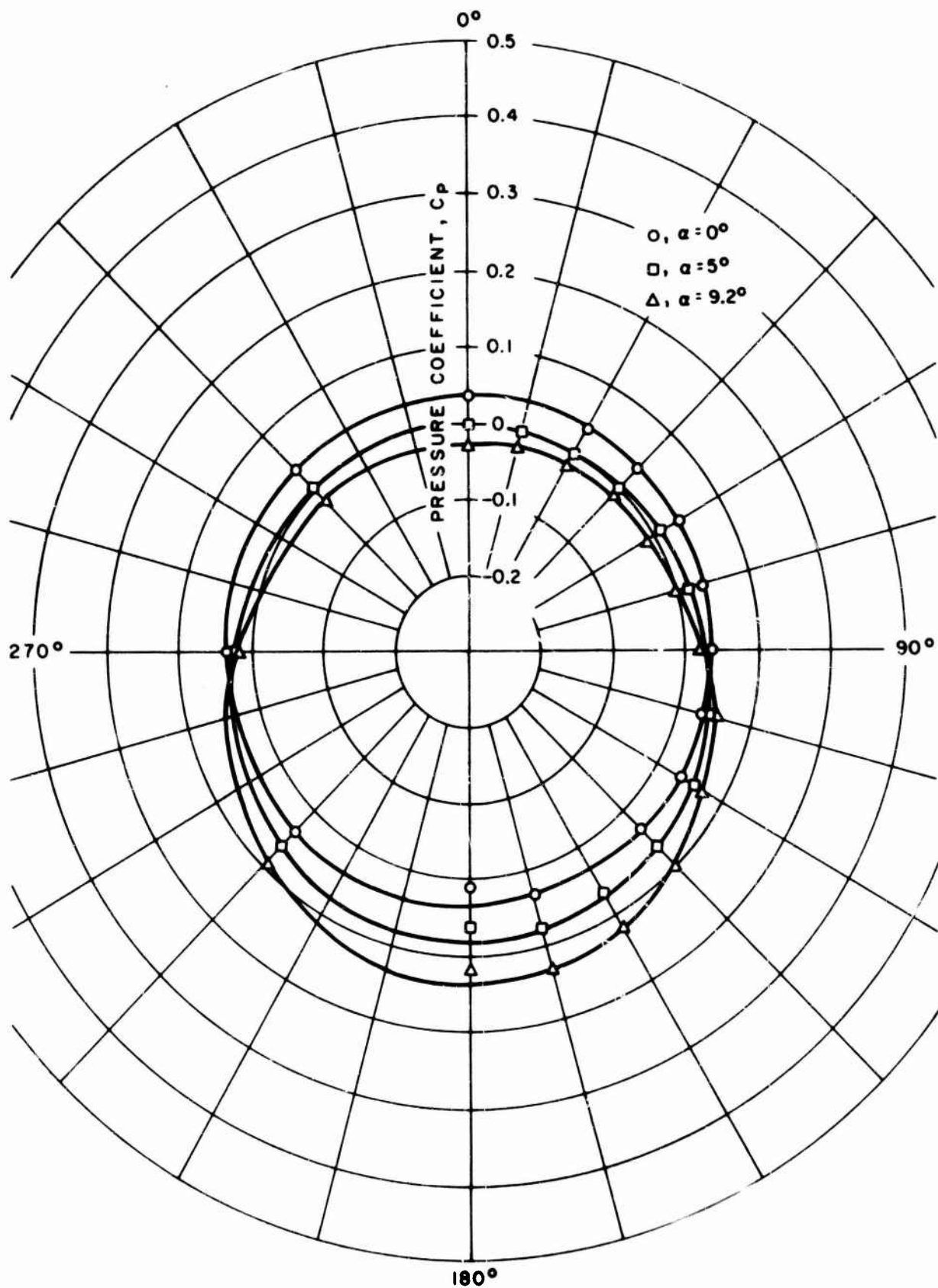
FIG. 29. Pressure Coefficient Polar Coordinates for
Pressure Tap No. 6, Pt. Mugu Data.
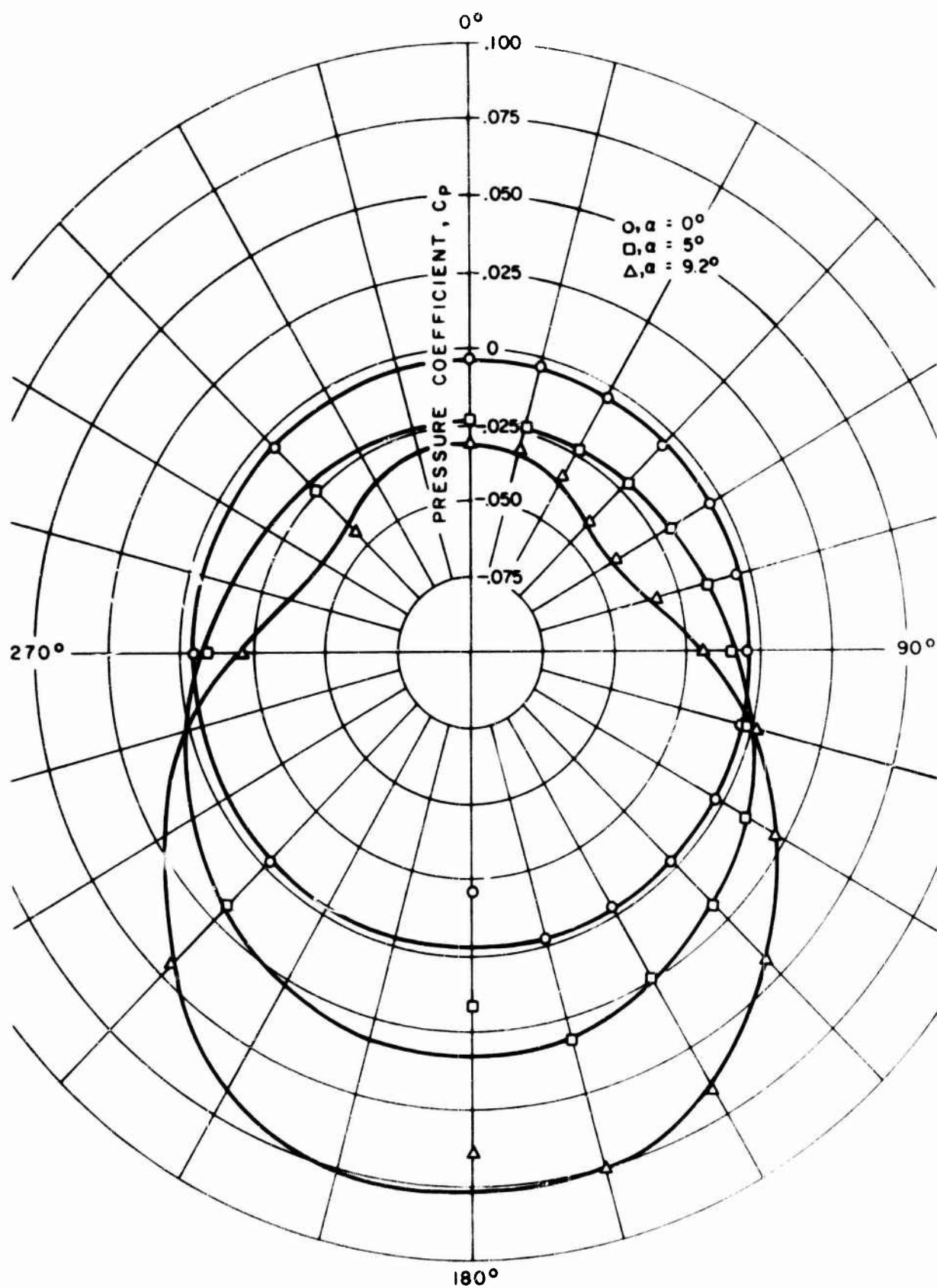
FIG. 30. Pressure Coefficient Polar Coordinates for
Pressure Tap No. 10, Pt. Mugu Data.
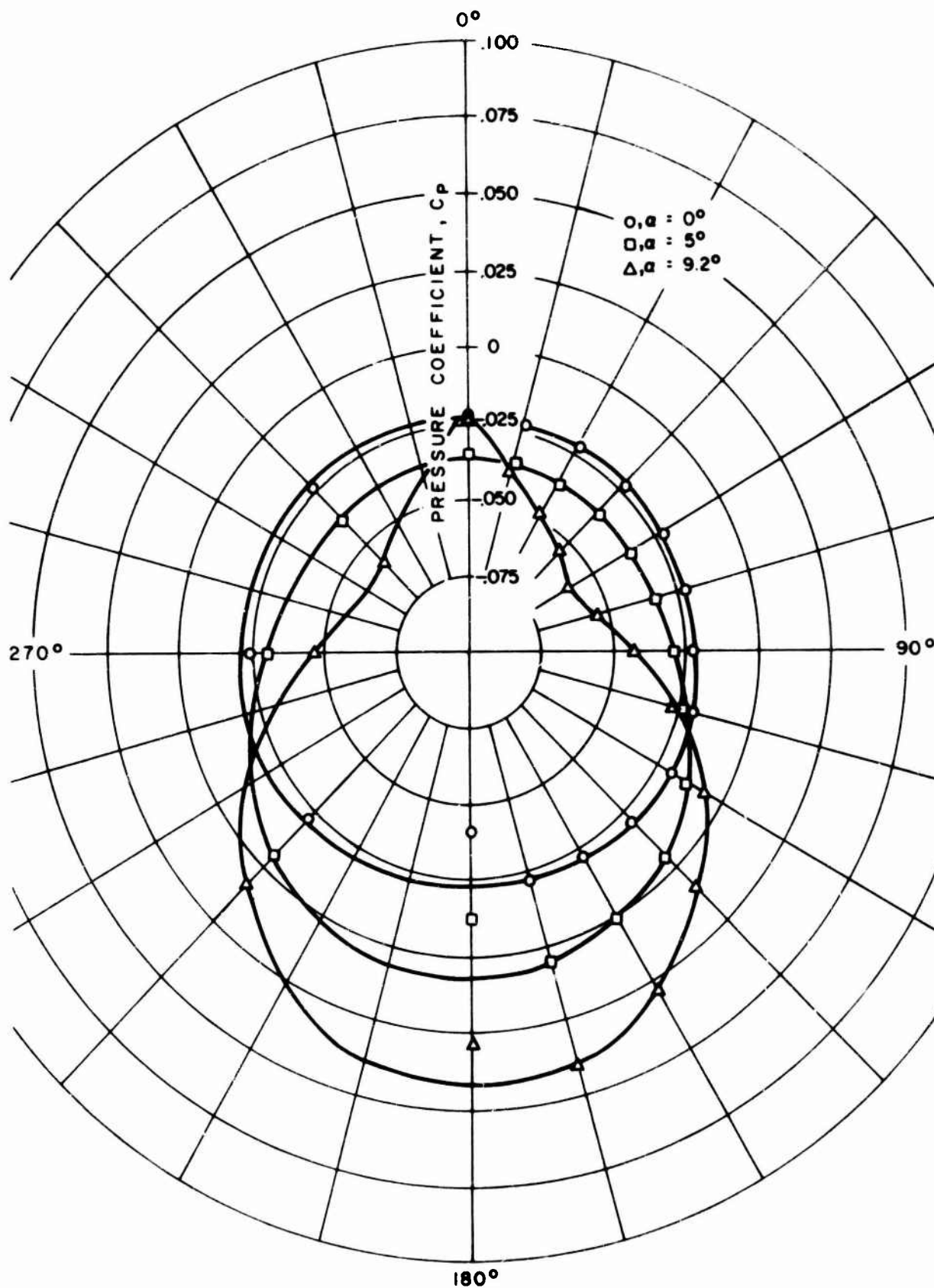
FIG. 31. Pressure Coefficient Polar Coordinates for
Pressure Tap No. 12, Pt. Mugu Data.

37
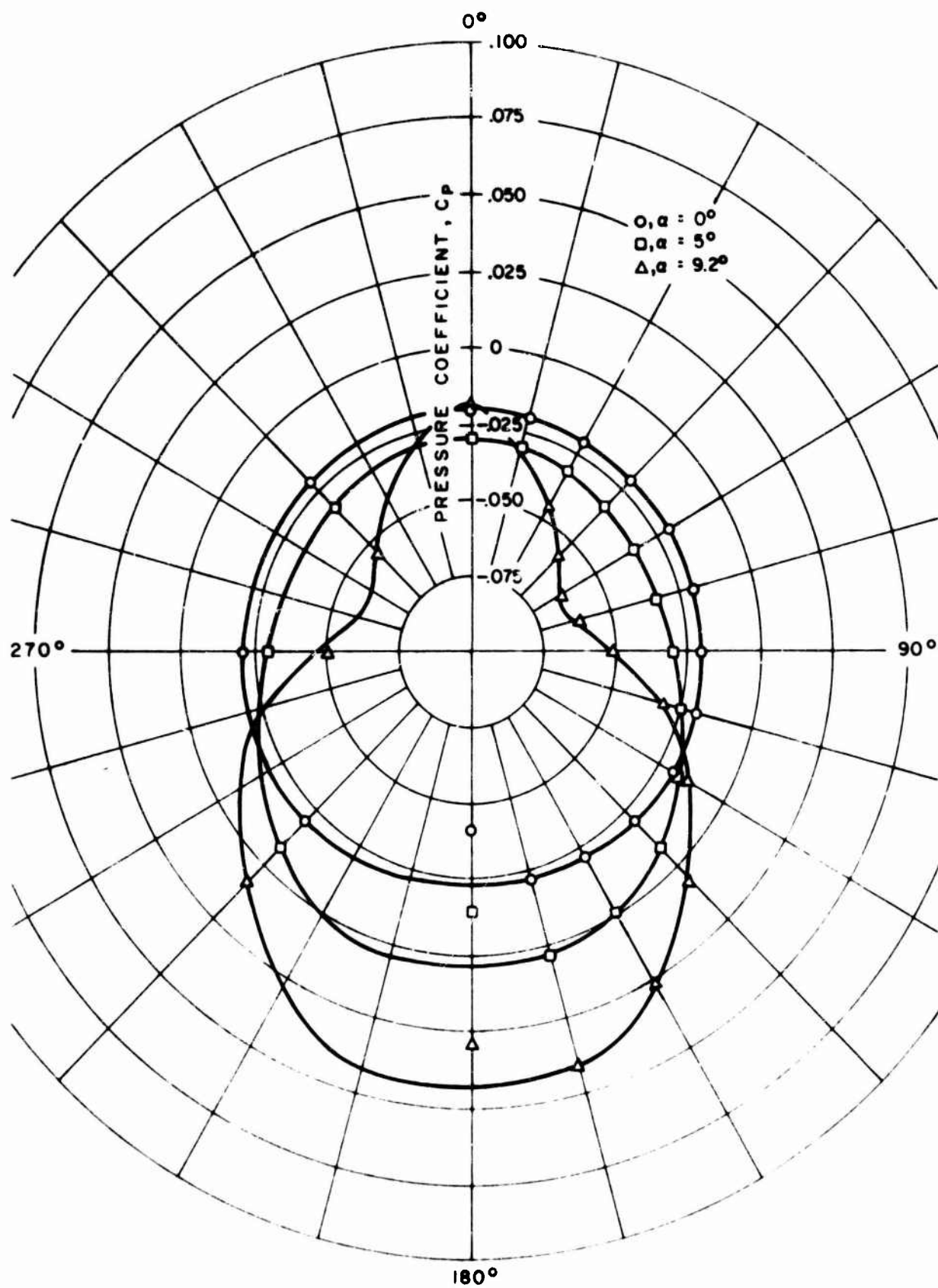
FIG. 32.   Pressure Coefficient Polar Coordinates for
Pressure Tap No. 14, Pt. Mugu Data.
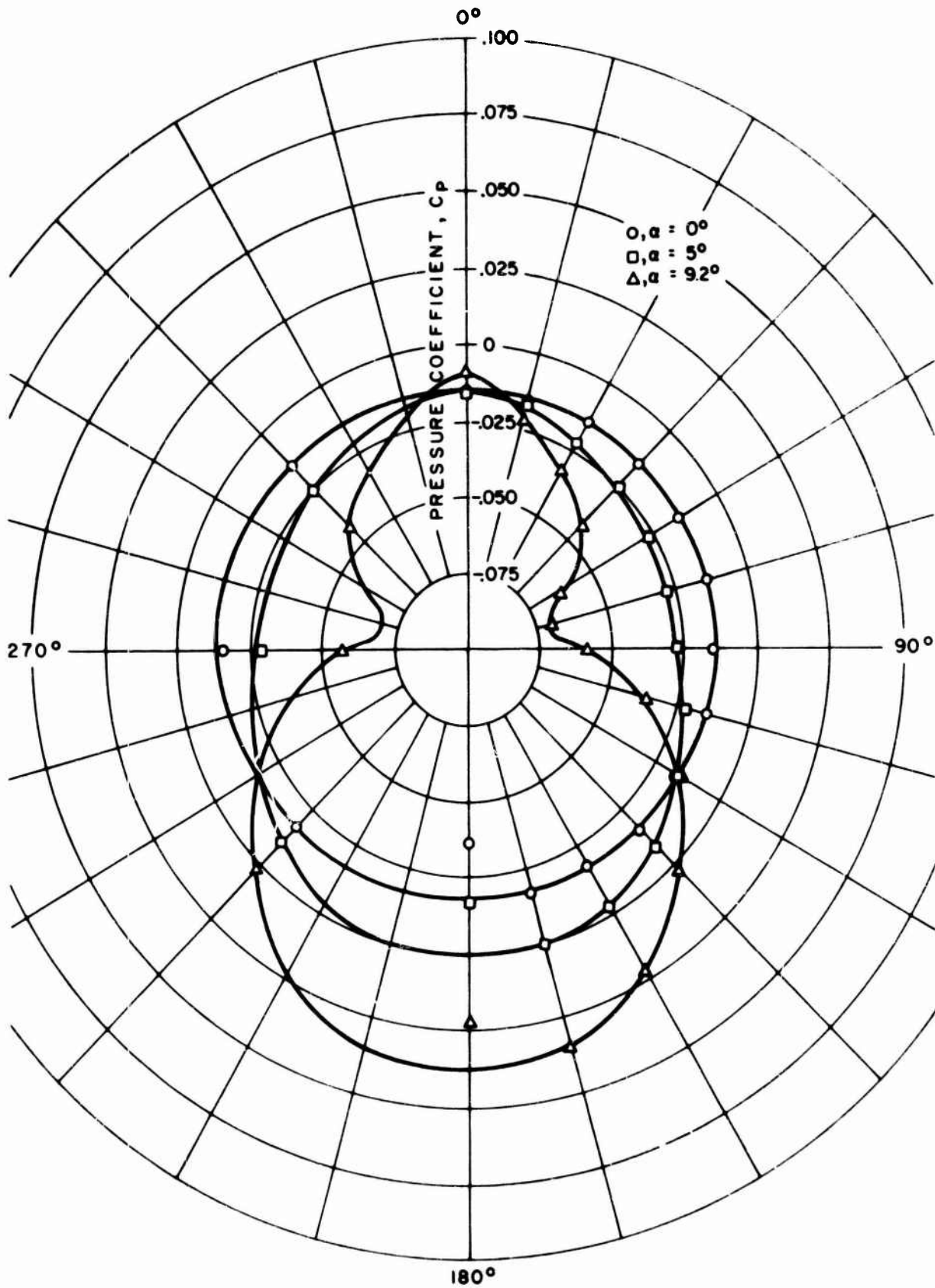
FIG. 33. Pressure Coefficient Polar Coordinates for
Pressure Tap No. 18, Pt. Mugu Data.
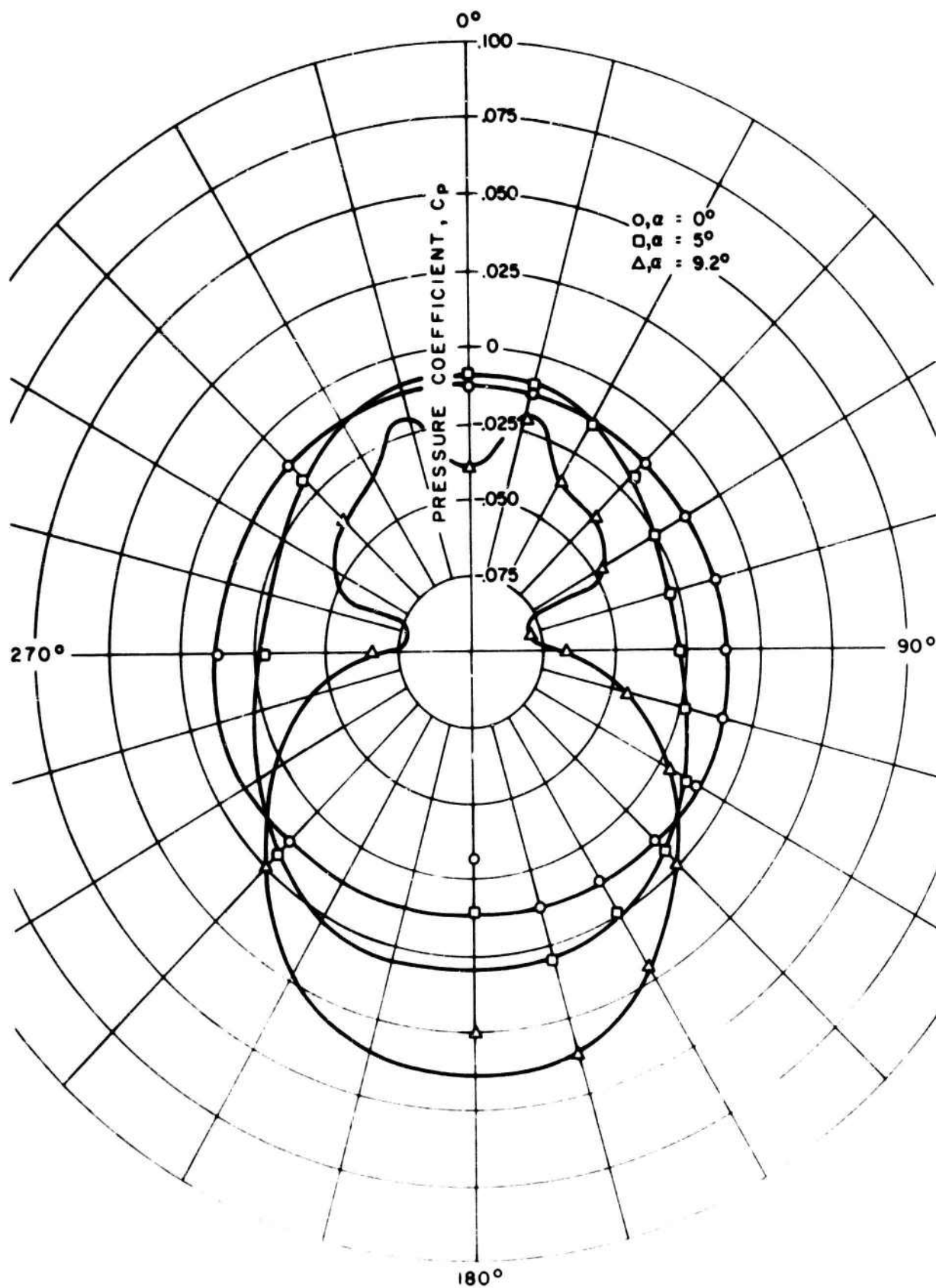
FIG. 34. Pressure Coefficient Polar Coordinates for Pressure Tap No. 22, Pt. Mugu Data.
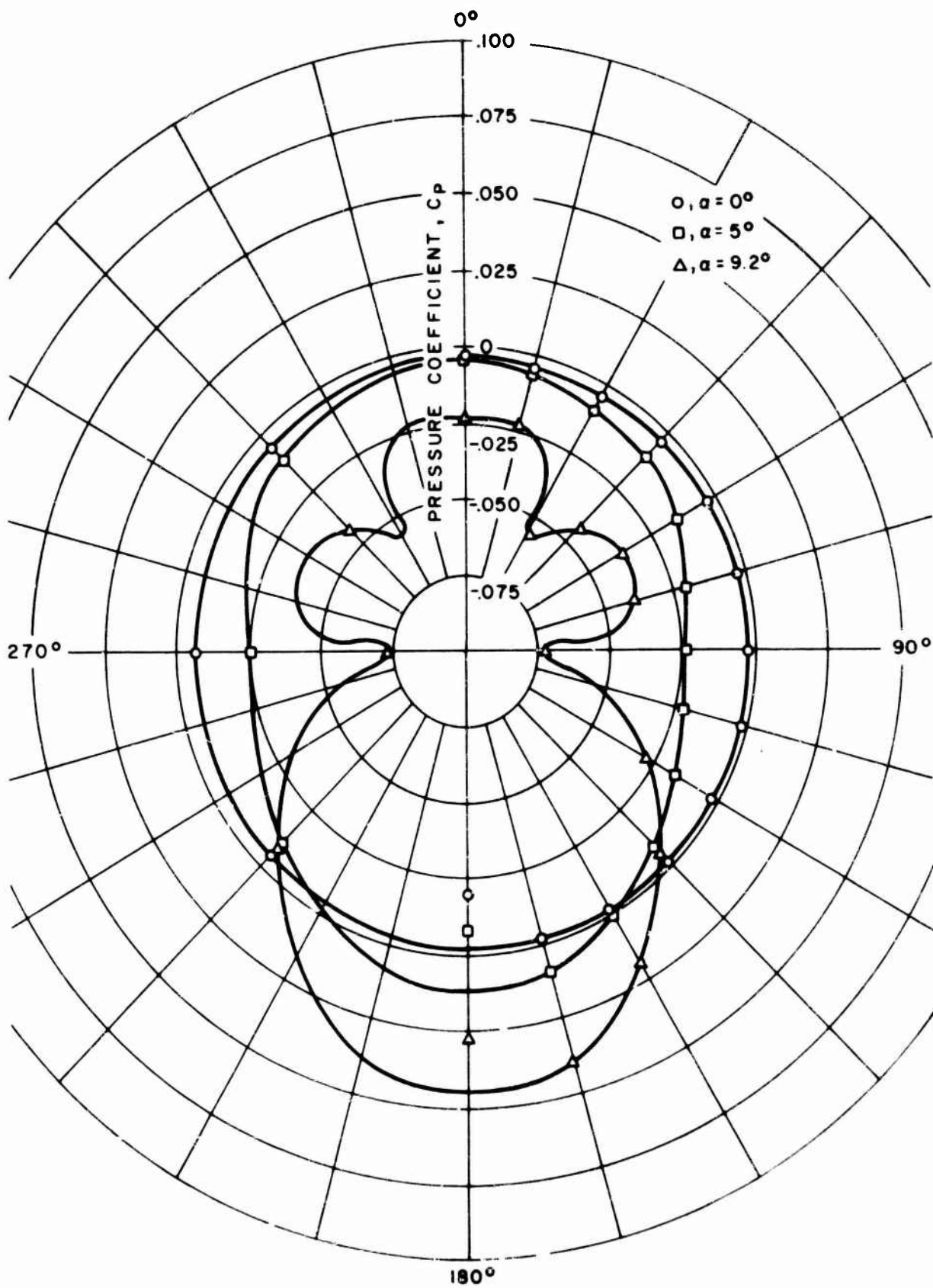
FIG. 35. Pressure Coefficient Polar Coordinates for
Pressure Tap No. 26, Pt. Mugu Data.
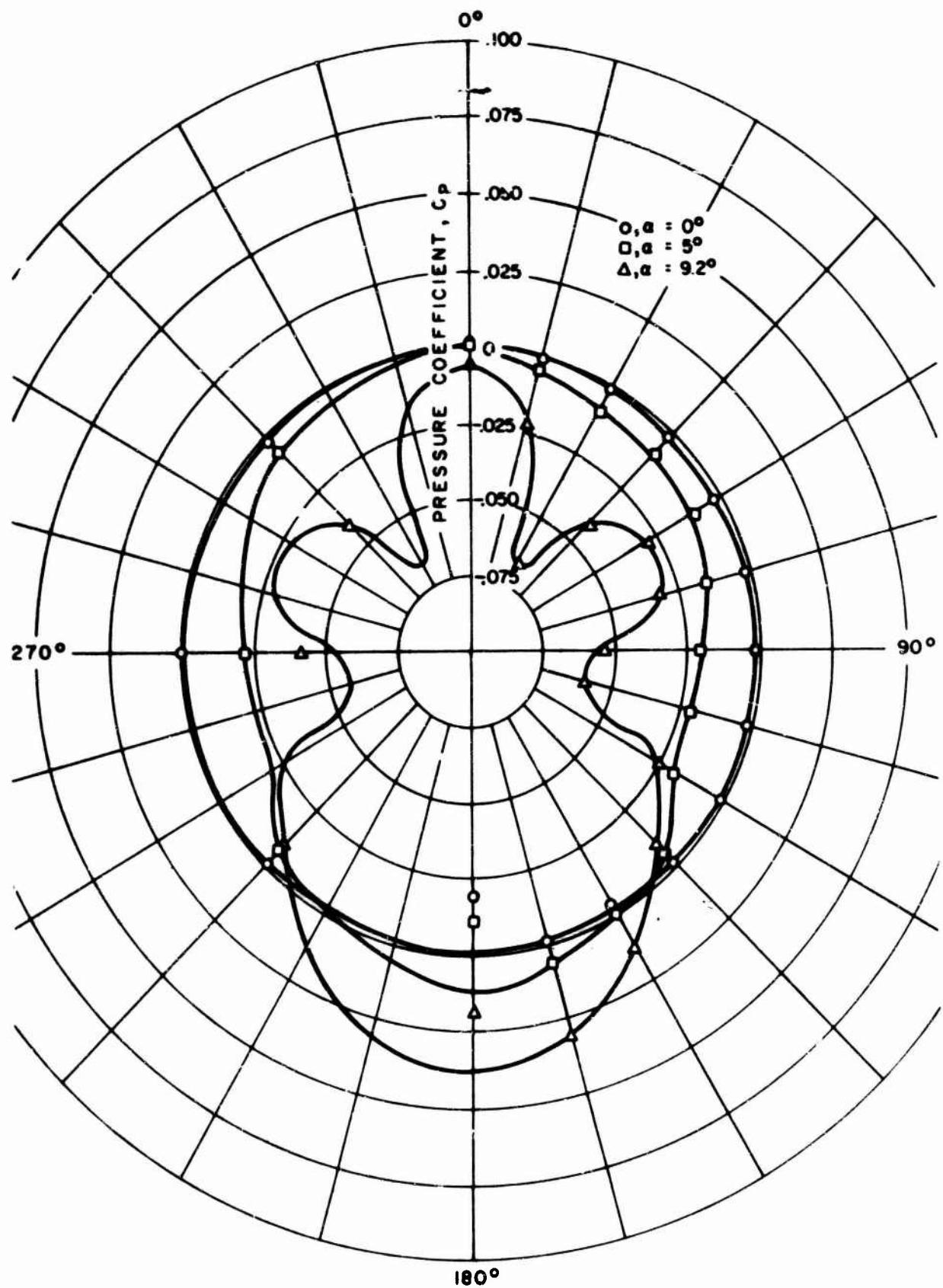
FIG. 36. Pressure Coefficient Polar Coordinates for
Pressure Tap No. 30, Pt. Mugu Data.

42

plots in Fig. 35 and 36 may possibly be due to the generation of trailing vortices on the downwind side of the body. The characteristics which lead to this observation are the downstream location of the variations (both circumferentially and longitudinally) and their occurrence only at high angles of attack. Since vortex generation is a viscous phenomenon, its apparent absence from the plotted MIT data for the same pressure tap stations may be taken as further evidence of the effect of the lowered viscosity in the Hot Core Facility.

In the preceding discussion, mention was made of the data points $\varphi = 0$ degree in the MIT plots. It appears that the data points at $\varphi = 180$ degrees in the Pt. Mugu plots are also obviously out of line with the general trend of the plotted curves. These data points are considered as having some bias inherent in their magnitudes due to either instrumentation errors or data processing errors. Although these data do not correlate well with the other polar-plotted data, they are reasonably valid within themselves to show the trend of the longitudinal pressure distribution when plotted in Cartesian coordinates.

AN EMPIRICAL TREATMENT OF THE CIRCUMFERENTIAL PRESSURE DISTRIBUTION

For practical applications such as the computation of heat transfer on bodies at angles of attack, it is frequently desirable to have simple mathematical expressions describe the circumferential pressure distribution. The use of rigorously derived mathematical procedures for the calculations of the pressure is usually difficult since the expressions, so obtained, are in almost every case complicated and generally apply to relatively idealized configurations only.

Where extremely accurate values are not required for the pressures and distribution patterns, it is possible to derive a fairly simple empirical expression for the circumferential pressure coefficients. This is accomplished by treating the inclined body as an inclined circular cylinder and by examining the flow thereon in the classical manner as having an axial component and a cross component of velocity, and introducing an arbitrary correction for the effects of viscosity.

Consider the body of revolution, illustrated in Fig. 37, at an angle of attack, α, with respect to the freestream direction. The freestream velocity, V, may be resolved into the axial and crossflow components, respectively:

$$v_a = V \cos \alpha \tag{1}$$

$$v_c = V \sin \alpha \tag{2}$$
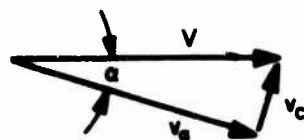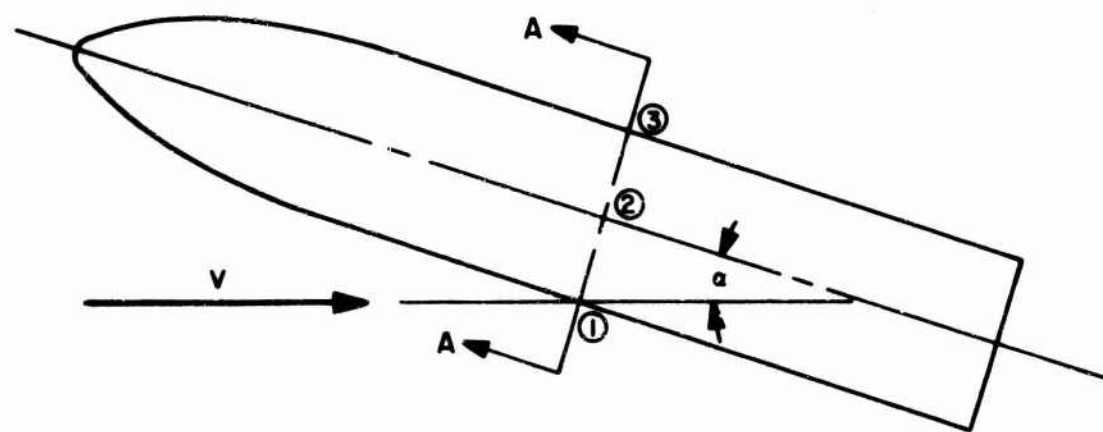
FLOW COMPONENTS AT ①
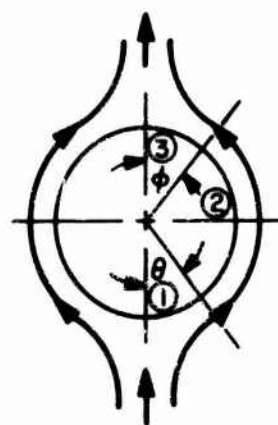
CROSSFLOW (IDEAL) AT
SECTION A-A
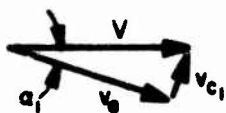
$v_{c_1} = V \sin \alpha$
$\alpha_1 = \alpha$

POINT ①
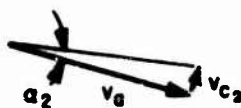
$\alpha_2 < \alpha$

POINT ②

$v_c = 0$
$\alpha_3 = \alpha$

POINT ③

ASSUMED FLOW AT BODY SURFACE POINTS

FIG. 37. Flow Components on Inclined Body.

The classical potential theory solution for the case of the circular cylinder placed normal to an incompressible, irrotational, uniform flow having a velocity, U, is

$$v_t = 2U \sin \theta \tag{3}$$

where v_t is the tangential velocity at the surface of the cylinder and θ is one of the polar coordinates of the point at which v_t is taken, the center of the coordinate system being placed on the axis of the cylinder as in Fig. 37.

Since U is the equivalent to the crossflow velocity, v_c (Eq. 2), Eq. 3 becomes

$$v_t = 2V \sin \alpha \sin \theta \tag{4}$$

At any point on the cylinder there is an axial component of the freestream velocity so that the velocity, v_r, at that point is the resultant of the axial and tangential (or crossflow) components. Therefore

$$v_r^2 = v_a^2 + v_t^2 = V^2 \cos^2 \alpha + 4V^2 \sin^2 \alpha \sin^2 \theta \tag{5}$$

Equation 5 is derived for inviscid fluids. For the real case, some adjustment must be made to the equation to compensate for the effect of viscosity. In Eq. 5, it may be arbitrarily assumed that the viscosity of the fluid will decrease the flow velocity by some factor $A^{1/2}$ which must act around the circumference of the body so that it is minimum on the windward side and maximum on the opposite side. Equation 5 may therefore be written

$$v_r^2 = V^2 \cos^2 \alpha + 4AV^2 \sin^2 \alpha \sin^2 \theta \sin^2 \frac{\theta}{2} \tag{6}$$

where

A $\sin^2 \theta/2$ is an arbitrary correction for the effects of viscosity on the crossflow velocity.

In addition to decreasing the crossflow velocity, the viscosity will tend to turn the resultant flow by adding a downward component of velocity so that a downwash effect results. If this downwash component is v_d, the net downwash effect, varying with the circumferential distance from the windward point, can be stated as

$$v_d = V \sin \alpha \sin \frac{\theta}{2} \tag{7}$$

45

where

V sin α is the maximum downwash component at the downwind side of the body.

The resultant velocity at any point around the circumference of the body (from Eq. 6 and 7) is approximately

$$v_R^2 = v_r^2 + v_d^2$$

$$= V^2 \cos^2 \alpha + 4AV^2 \sin^2 \alpha \sin^2 \theta \sin^2 \frac{\theta}{2} + V^2 \sin^2 \alpha \sin^2 \frac{\theta}{2} \qquad (8)$$

To determine the pressures on the body of revolution by means of Eq. 8, it is necessary to relate the velocities to pressures by means of Bernoulli's equation for incompressible flow:

$$\frac{P_1}{w_1} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{w_2} + \frac{V_2^2}{2g} + z_2 \qquad (9)$$

The subscripts 1 and 2, respectively, refer to two points in the flow upstream and downstream; p, the static pressure; V, the velocity; w, the specific weight; g, the "gravitational constant"; and z, the "elevation head."

Letting $z_1 = z_2$ and rearranging Eq. 9,

$$P_1 + \frac{w_1}{g} \frac{V_1^2}{2} = P_2 + \frac{w_2}{g} \frac{V_2^2}{2} \qquad (10)$$

Since the fluid density, $\rho = w/g$ and $\rho_1 = \rho_2$ for incompressible flow, Eq. 10 may be written

$$P_2 - P_1 = \frac{\rho}{2} V_1^2 - \frac{\rho}{2} V_2^2 \qquad (11)$$

The pressure coefficient is defined as

$$C_p = \frac{\Delta p}{q} = \frac{P_2 - P_1}{\rho \frac{V_1^2}{2}} \qquad (12)$$

Therefore, substituting from Eq. 11 into Eq. 12

$$C_p = \frac{\frac{\rho}{2} V_1^2 - \frac{\rho}{2} V_2^2}{\rho \frac{V_1^2}{2}} = 1 - \left(\frac{V_2}{V_1}\right)^2 \tag{13}$$

Combining Eq. 8 and 13, and letting $V_1 = V$,

$$C_p = 1 - \cos^2 \alpha - 4A \sin^2 \alpha \sin^2 \theta \sin^2 \frac{\theta}{2} - \sin^2 \alpha \sin^2 \frac{\theta}{2} \tag{14}$$

The validity of Eq. 14 has been checked to a limited extent by comparing the calculated pressure distribution with the data from the Pt. Mugu and MIT wind-tunnel tests. By carefully choosing the values for the constant A, it is possible to obtain reasonably good fits to the experimental data.

Figures 38 and 39 show the results of the calculation of the pressure coefficients, using Eq. 14 in comparison with the experimental data obtained in the Pt. Mugu wind-tunnel tests. The curves shown in these figures were obtained for the conditions $\alpha = 9.2$ degrees and $A = 1$. There appears to be reasonably good agreement between the validity in the assumptions made in deriving Eq. 14.

Figure 39 shows that the crossflow effect alone does not establish the nature of the circumferential pressure distribution. The multiple-lobe experimental data curve for the 9.2-degree angle of attack case indicates the probable presence of relatively large vortex fields such as those described in Ref. 5 and 6. These vortex fields superpose additional crossflow velocities upon the body, thereby leading to the variations in pressure distribution from those of the ideal theoretical curves.

It does not require any detailed calculations to note that using the value for A, discussed previously, will not accurately fit the MIT data. It is evident, however, from the results of experiments such as those presented in Ref. 1 and 6, that the shape of the circumferential pressure distribution curve, as obtained from the Pt. Mugu data, is fairly typical. From this viewpoint, the MIT data may have some inherent characteristics possibly due to test conditions which may not be common with the other experiments.

Significantly different features of the MIT experiments, which are immediately obvious, are the stagnation temperature and the Reynolds number. The MIT tests, unlike the others, had relatively high stagnation and freestream temperatures which undoubtedly resulted in lower
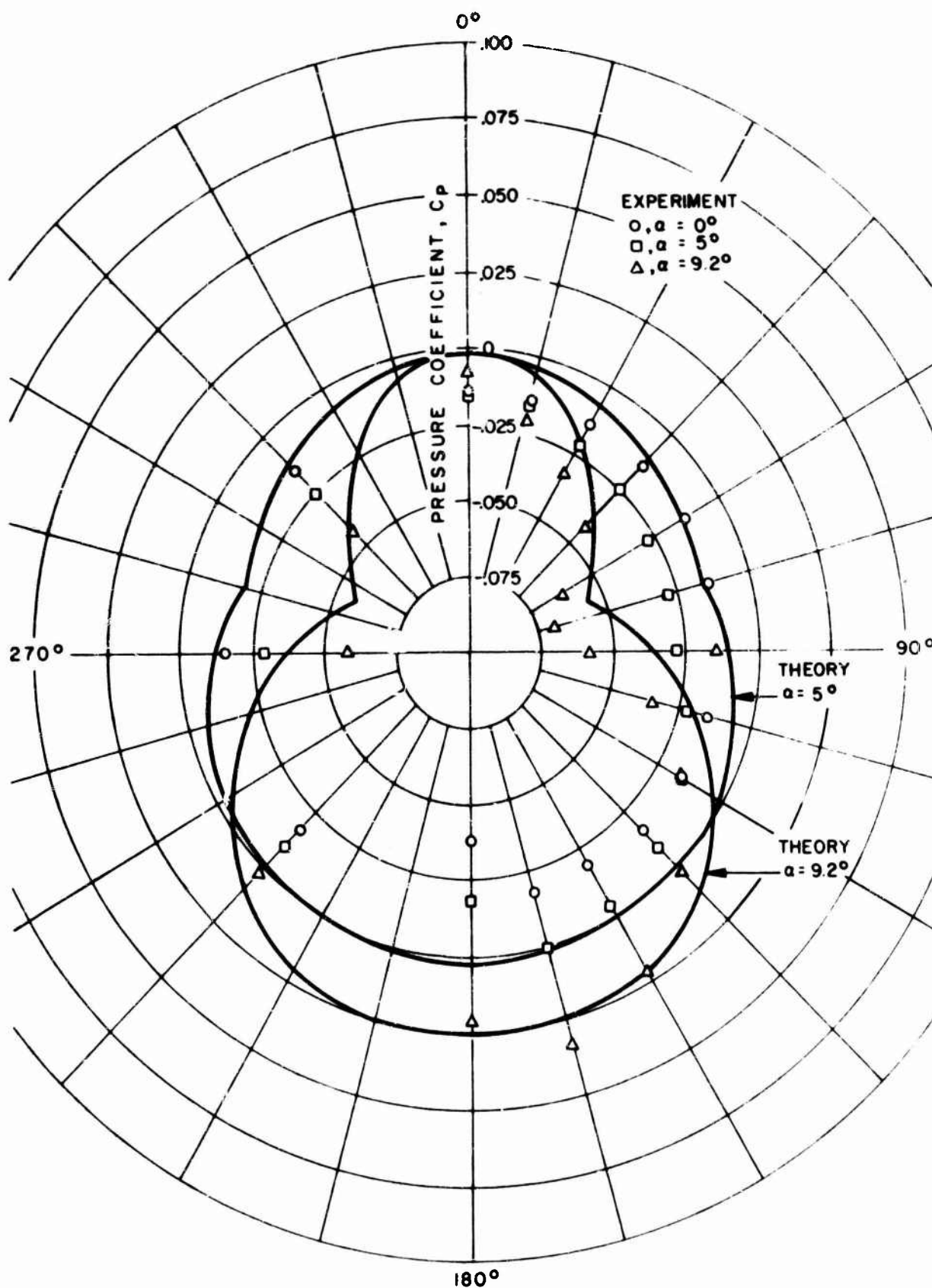
FIG. 38. Comparison of Theory With Experimental
Data, Pt. Mugu Data.
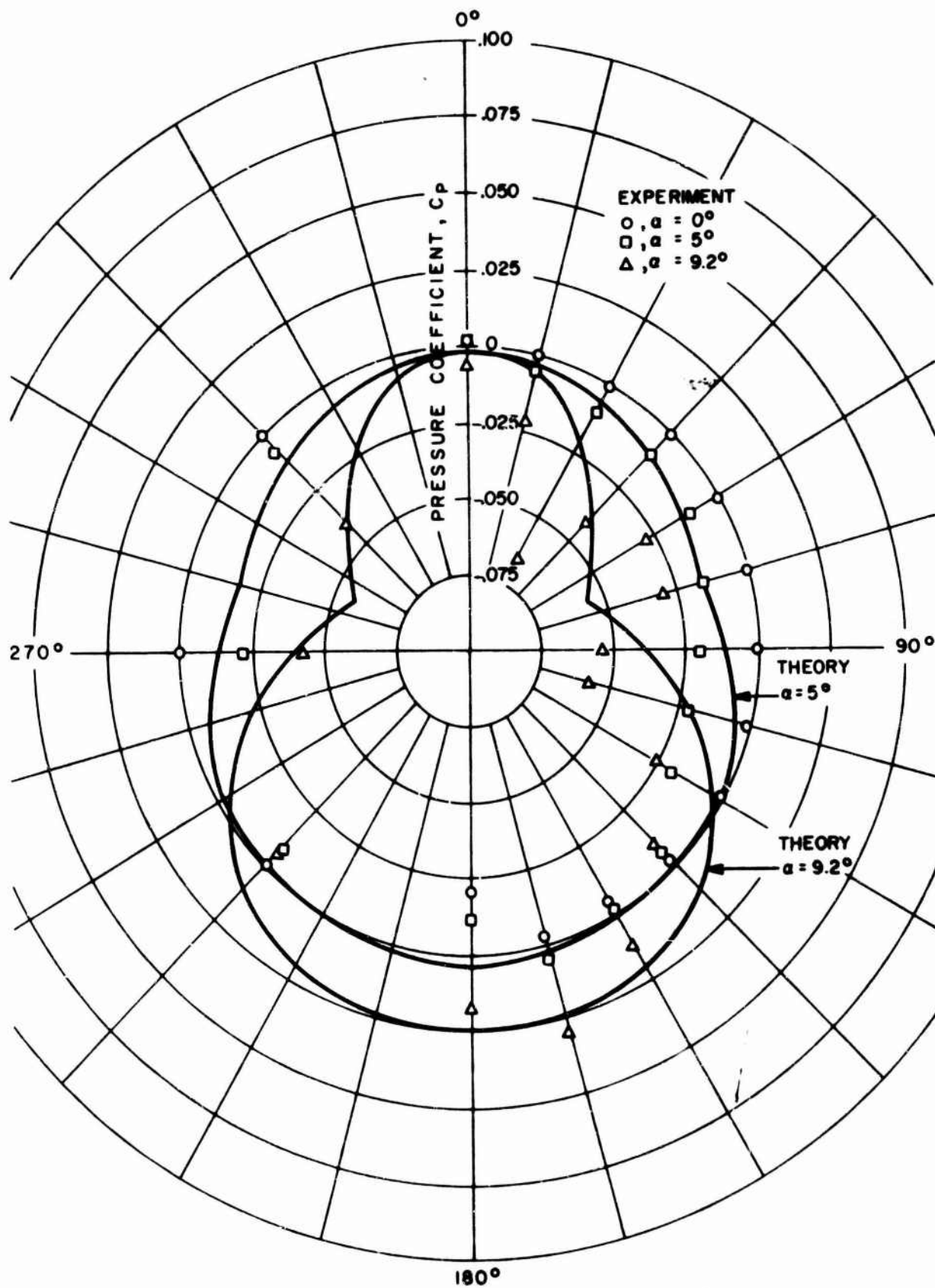
FIG. 39. Comparison of Theory With Experimental
Data, Pt. Mugu Data.

fluid viscosities. In addition, the Reynolds number was much lower at this facility than in the other wind tunnel. On the basis of the single MIT wind-tunnel test program, therefore, it may be conjectured that the combination of the low Reynolds number and viscosity was responsible for the different shape of the MIT curves as compared to the Pt. Mugu pressure distributions.

To fit Eq. 14 to the MIT data, it is apparent that A must be quite small in value. The result of letting A be zero as a first approximation is shown in Fig. 40, as compared to the MIT data. It appears, in this case at least, that the general shapes of the data curve and the theoretical curve are similar and that the constant A is in some manner sensitive to both low viscosities and low Reynolds number. Without further tests to investigate the effects of viscosity and Reynolds number, it is not practical to draw any firm conclusions on the variation of the constant A.

CONCLUSION

The circumferential pressure distribution on inclined bodies of revolution varies significantly from the uniform values obtained at zero angle of attack. This variation from the zero-angle pressure distribution is not only in itself not a smooth change, but it also exhibits local trends indicating the presence of higher-order effects and viscous phenomena.

In cases where the freestream viscosities are approximately those normally found in actual flight, there appear to be two basic sources of these variations. The first and most obvious source is the normal component of the flow across the body due to the angle of attack; the second is the more complicated effect of the formation of trailing vortices on the downwind side of the body.

The viscous effects of the flow around an inclined body predominantly appear to introduce trends which tend to change the polar-plotted pressure coefficient curves toward an elliptical pattern with cusps at the sides of the body while the vortex effects tend to induce similar cusping trends at or near the downwind region.

For the region of the cylindrical body downstream of the nose-body juncture, a simple empirical expression which does not include the effects of vortex formation may be used to describe the circumferential pressure distribution. The empirical expression appears to be adequate for use in computations where a rough knowledge of the pressure distribution is required, such as in heat-transfer studies.
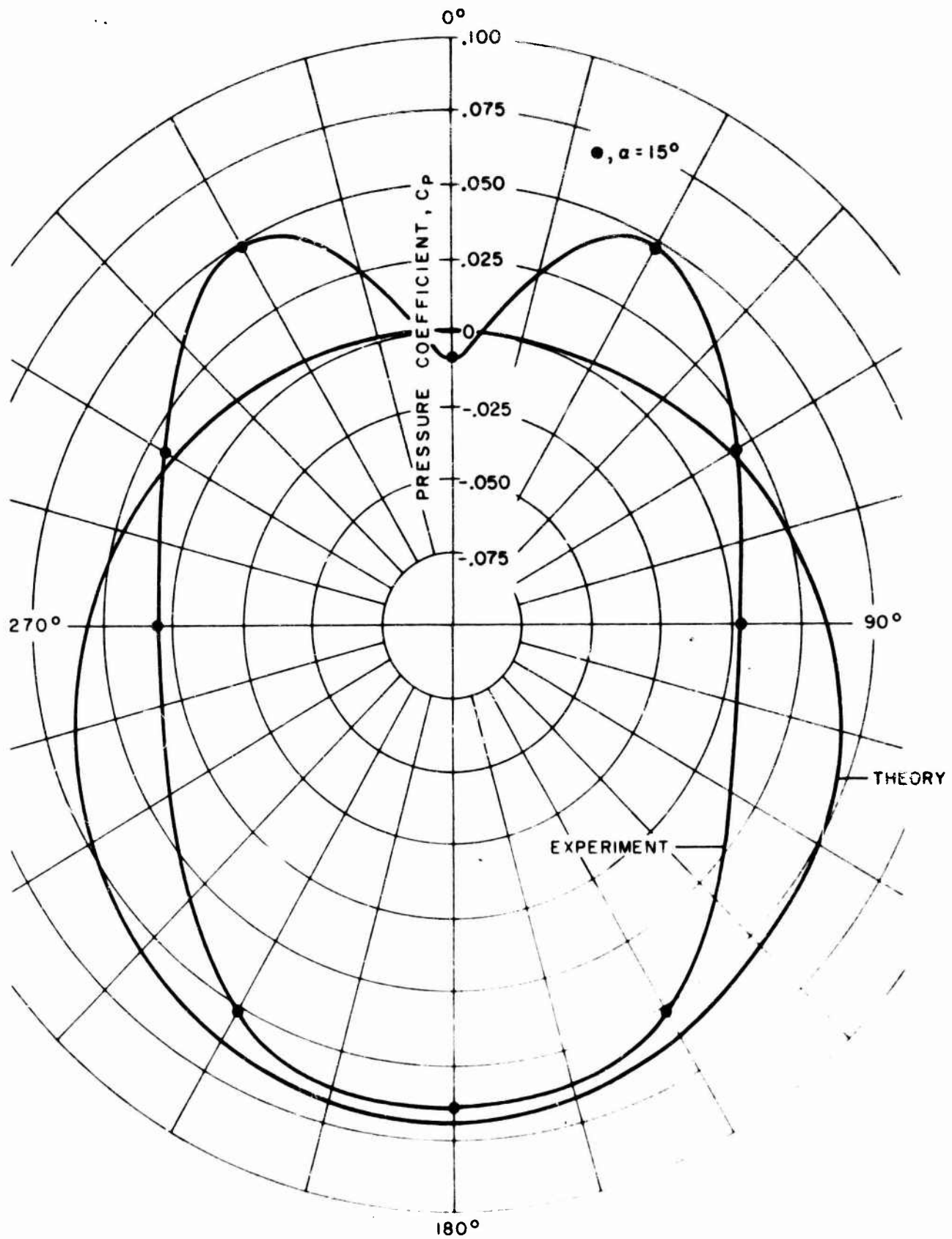
FIG. 40. Comparison of Theory With Experimental
Data, MIT Data.

51

A brief examination of the experimental data shows that although the empirical expression derived in this report is adequate for the cylindrical afterbody, the nose region pressure distribution is not accurately described. It appears reasonable to expect, however, that the equations may be modified in a simple manner to adequately fit the data for the forward parts of the bodies of revolution. When this is accomplished, it should also become evident that some experimental data will be needed to determine the values of the constants of proportionality which will be required in the application of the empirical expressions. These modifications to the empirical equations and experimental values for the constants will also improve the accuracy of the results for their applications to the cylindrical body regions.

The problem of the effects of the trailing vortices on the pressure distributions is one which requires a complete study in itself. It is also one which probably will not lend itself to a simple treatment. Because this problem is important when considering the pressure at high angles of attack, it is highly desirable that some analysis be made, possibly a semi-empirical procedure such as that developed in this report for the crossflow problem.

Appendix A

NOTS INDEX TO WIND-TUNNEL TEST DATA
FROM MIT AND PT. MUGU

To avoid confusion in this report, Appendix A serves as an index to the recorded data obtained in the MIT (Appendix B) and Pt. Mugu (Appendix C) wind-tunnel tests. In Table 3, the first column (NW 8448, the number of this report) is a list of arbitrary numbers which correlate the experimental pressure tap numbers designated in the tests at the respective facilities.

TABLE 3. Experimental Pressure Tap Numbers

Pressure Tap Numbers			Pressure Tap Numbers		
NW 8448	MIT	Pt. Mugu	NW 8448	MIT	Pt. Mugu
1	1	1	18	20	22
2	3	6	19	21	23
3	5	7	20	22	24
4	6	8	21	23	25
5	7	9	22	24	26
6	8	10	23	25	27
7	9	11	24	26	28
8	10	12	25	27	29
9	11	13	26	28	30
10	12	14	27	29	31
11	13	15	28	30	32
12	14	16	29	31	33
13	15	17	30	32	34
14	16	18	31	2	2
15	17	19	32	4	3
16	18	20	33	33	4
17	19	21	34	34	5

Appendix B

MIT WIND-TUNNEL TEST DATA

As part of the continuing study of the aerodynamics of a body of revolution at angle of attack, heat-transfer studies on a blunt body at angle of attack were conducted for NOTS in the MIT Naval Supersonic Laboratory, Cambridge, Mass. During this experimental work at MIT, pressure data were obtained. In Tables 4 through 27 of this appendix, these data are recorded as follows:

φ = circumferential angular position measured from downward station

α = angle of attack

tap = pressure tap station

p/p_o = pressure ratio

C_p = pressure coefficient

TABLE 4. $\varphi = 0$ and $\alpha = 0$ Degrees

TAP	P/P_0	C_P	LOCAL MACH
1	0.50303	0.84317	1.08
2	0.49945	0.83641	1.04
3	0.09924	0.08028	2.16
4	0.10642	0.09384	2.12
5	0.08848	0.05995	2.24
6	0.08489	0.05317	2.26
7	0.07950	0.04298	2.30
8	0.07950	0.04298	2.30
9	0.07412	0.03282	2.35
10	0.06873	0.02263	2.40
11	0.06694	0.01925	2.41
12	0.06514	0.01585	2.43
13	0.06155	0.00907	2.47
14	0.05797	0.00230	2.51
15	0.05976	0.00569	2.49
16	0.05797	0.00230	2.51
17	0.05797	0.00230	2.51
18	0.05617	-0.00110	2.53
19	0.05258	-0.00788	2.57
20	0.05976	0.00569	2.51
21	0.06335	0.01247	2.45
22	0.06694	0.01925	2.41
23	0.06335	0.01247	2.45
24	0.06514	0.01585	2.43
25	0.06694	0.01925	2.41
26	0.06873	0.02263	2.40
27	0.06873	0.02263	2.40
28	0.06690	0.01918	2.41
29	0.06873	0.02263	2.40
30	0.07053	0.02604	2.38
31	0.07232	0.02942	2.37
32	0.07053	0.02604	2.38
33	0.07412	0.03282	2.35
34	0.07592	0.03622	2.33

TABLE 5. $\varphi = 0$ and $\alpha = 5.00$ Degrees

TAP	P/P_0	C_P	LOCAL MACH
1	0.40506	0.65808	1.21
2	0.62938	1.08189	0.84
3	0.07663	0.03756	2.33
4	0.13944	0.15623	1.94
5	0.06945	0.02399	2.39
6	0.06858	0.02235	2.40
7	0.06407	0.01383	2.44
8	0.06228	0.01045	2.46
9	0.06098	0.00799	2.48
10	0.05869	0.00367	2.50
11	0.05509	-0.00314	2.54
12	0.05309	-0.00691	2.54
13	0.05151	-0.00990	2.58
14	0.04971	-0.01330	2.61
15	0.05151	-0.00990	2.58
16	0.05151	-0.00990	2.58
17	0.05151	-0.00990	2.58
18	0.05330	-0.00652	2.56
19	0.05151	-0.00990	2.58
20	0.05689	0.00026	2.52
21	0.02279	-0.06416	3.12
22	0.02638	-0.05738	3.02
23	0.05869	0.00367	2.50
24	0.06048	0.00705	2.48
25	0.06048	0.00705	2.48
26	0.06048	0.00705	2.48
27	0.06048	0.00705	2.48
28	0.06228	0.01045	2.46
29	0.06228	0.01045	2.46
30	0.06407	0.01383	2.44
31	0.06967	0.02441	2.44
32	0.06856	0.02231	2.42
33	0.07125	0.02740	2.37
34	0.06944	0.02398	2.39

TABLE 6. $\varphi = 0$ and $\alpha = 10.00$ Degrees

TAP	P/P_0	C_P	LOCAL MACH
1	0.32430	0.50549	1.38
2	0.72450	1.26161	0.69
3	0.06945	0.02399	2.39
4	0.19149	0.25457	1.74
5	0.06586	0.01721	2.42
6	0.06407	0.01383	2.44
7	0.06407	0.01383	2.44
8	0.06228	0.01045	2.46
9	0.06048	0.00705	2.48
10	0.05509	-0.00314	2.54
11	0.05330	-0.00652	2.56
12	0.05330	-0.00652	2.56
13	0.04971	-0.01330	2.61
14	0.04792	-0.01668	2.63
15	0.04971	-0.01330	2.61
16	0.04792	-0.01668	2.63
17	0.04792	-0.01668	2.63
18	0.04971	-0.01330	2.61
19	0.04613	-0.02006	2.65
20	0.05150	-0.00992	2.58
21	0.05330	-0.00652	2.56
22	0.06227	0.01043	2.46
23	0.05509	-0.00314	2.54
24	0.05509	-0.00314	2.54
25	0.05330	-0.00652	2.56
26	0.05509	-0.00314	2.54
27	0.05509	-0.00314	2.54
28	0.05509	-0.00314	2.54
29	0.05869	0.00367	2.50
30	0.06048	0.00705	2.48
31	0.06407	0.01383	2.44
32	0.06765	0.02059	2.41
33	0.08022	0.04434	2.30
34	0.07304	0.03078	2.36

TABLE 7. $\varphi = 0$ and $\alpha = 15.00$ Degrees

TAP	P/P_0	C_P	LOCAL MACH
1	0.02700	-0.05621	1.50
2	0.77470	1.35645	0.61
3	0.06410	0.01389	2.44
4	0.24710	0.35964	1.57
5	0.06410	0.01389	2.44
6	0.06050	0.00709	2.48
7	0.06050	0.00709	2.48
8	0.06050	0.00709	2.48
9	0.05870	0.00368	2.50
10	0.05330	-0.00652	2.56
11	0.05150	-0.00992	2.58
12	0.05150	-0.00992	2.58
13	0.04790	-0.01672	2.63
14	0.04610	-0.02012	2.65
15	0.04790	-0.01672	2.63
16	0.04610	-0.02012	2.65
17	0.04610	-0.02012	2.65
18	0.04610	-0.02012	2.65
19	0.04430	-0.02352	2.68
20	0.04970	-0.01332	2.61
21	0.05330	-0.00652	2.56
22	0.05330	-0.00652	2.56
23	0.05150	-0.00992	2.58
24	0.05330	-0.00652	2.56
25	0.05150	-0.00992	2.58
26	0.05330	-0.00652	2.56
27	0.05150	-0.00992	2.58
28	0.05150	-0.00992	2.58
29	0.05510	-0.00312	2.54
30	0.05510	-0.00312	2.54
31	0.06590	0.01729	2.43
32	0.06940	0.02390	2.39
33	0.06410	0.01389	2.44
34	0.04250	-0.02692	2.24

TABLE 8. $\varphi = 30$ and $\alpha = 5.00$ Degrees

TAP	P/P_0	C_P	LOCAL MACH
1	0.43250	0.70992	1.16
2	0.59230	1.01184	0.90
3	0.10410	0.08946	2.13
4	0.14000	0.15729	1.94
5	0.09360	0.06962	2.20
6	0.08980	0.06244	2.22
7	0.08670	0.05659	2.25
8	0.08440	0.05224	2.27
9	0.08440	0.05224	2.27
10	0.08080	0.04544	2.29
11	0.07900	0.04204	2.31
12	0.07710	0.03845	2.32
13	0.07540	0.03524	2.34
14	0.07360	0.03184	2.35
15	0.07540	0.03524	2.34
16	0.07540	0.03524	2.34
17	0.07720	0.03864	2.32
18	0.07720	0.03864	2.32
19	0.07720	0.03864	2.32
20	0.08260	0.04884	2.28
21	0.08440	0.05224	2.27
22	0.08620	0.05564	2.25
23	0.08440	0.05224	2.27
24	0.08620	0.05564	2.25
25	0.08440	0.05224	2.27
26	0.08620	0.05564	2.25
27	0.08440	0.05224	2.27
28	0.08620	0.05564	2.25
29	0.08800	0.05904	2.24
30	0.08620	0.05564	2.25
31	0.08620	0.05564	2.25
32	0.08800	0.05904	2.24
33	0.09510	0.07246	2.19
34	0.09890	0.07964	2.18

TABLE 9. $\varphi = 30$ and $\alpha = 10.00$ Degrees

TAP	P/P_0	C_p	LOCAL MACH
1	0.35170	0.55726	1.32
2	0.67120	1.16090	0.78
3	0.08790	0.05885	2.24
4	0.16330	0.20131	1.84
5	0.08430	0.05205	2.27
6	0.08070	0.04525	2.29
7	0.07890	0.04185	2.31
8	0.07890	0.04185	2.31
9	0.07890	0.04185	2.31
10	0.07360	0.03184	2.35
11	0.07180	0.02843	2.37
12	0.07000	0.02503	2.39
13	0.06820	0.02163	2.40
14	0.06460	0.01483	2.44
15	0.06820	0.02163	2.40
16	0.06460	0.01483	2.44
17	0.06460	0.01483	2.44
18	0.06460	0.01483	2.44
19	0.06280	0.01143	2.45
20	0.07000	0.02503	2.39
21	0.07180	0.02843	2.37
22	0.07360	0.03184	2.35
23	0.07180	0.02843	2.37
24	0.07180	0.02843	2.37
25	0.07000	0.02503	2.39
26	0.07180	0.02843	2.37
27	0.07000	0.02503	2.39
28	0.07180	0.02843	2.37
29	0.07540	0.03524	2.34
30	0.07360	0.03184	2.35
31	0.07360	0.03184	2.35
32	0.07360	0.03184	2.35
33	0.08970	0.06225	2.23
34	0.08790	0.05885	2.24

TABLE 10. $\varphi = 30$ and $\alpha = 15.00$ Degrees

TAP	P/P$_0$	C$_p$	LOCAL MACH
1	0.30080	0.46109	1.43
2	0.73700	1.28522	0.67
3	0.08730	0.05772	2.24
4	0.21830	0.30522	1.65
5	0.08730	0.05772	2.64
6	0.08370	0.05092	2.27
7	0.08010	0.04412	2.30
8	0.08190	0.04752	2.28
9	0.08010	0.04412	2.30
10	0.07650	0.03731	2.33
11	0.07470	0.03391	2.34
12	0.07470	0.03391	2.34
13	0.07110	0.02711	2.37
14	0.07110	0.02711	2.37
15	0.07290	0.03051	2.36
16	0.07110	0.02711	2.37
17	0.06930	0.02371	2.39
18	0.07110	0.02711	2.37
19	0.07110	0.02711	2.37
20	0.07650	0.03731	2.33
21	0.08010	0.04412	2.30
22	0.08190	0.04752	2.28
23	0.08010	0.04412	2.30
24	0.08190	0.04752	2.28
25	0.08010	0.04412	2.30
26	0.08190	0.04752	2.28
27	0.07830	0.04072	2.31
28	0.08010	0.04412	2.30
29	0.08370	0.05092	2.27
30	0.08190	0.04752	2.28
31	0.08010	0.04412	2.30
32	0.07830	0.04072	2.31
33	0.11490	0.10987	2.07
34	0.10881	0.09836	2.10

TABLE 11. $\varphi = 60$ and $\alpha = 5.00$ Degrees

TAP	P/P_O	C_p	LOCAL MACH
1	0.46060	0.76301	1.11
2	0.56110	0.95289	0.95
3	0.10700	0.09494	2.11
4	0.13400	0.14595	1.97
5	0.09990	0.08152	2.16
6	0.09450	0.07132	2.19
7	0.09090	0.06452	2.22
8	0.08910	0.06112	2.23
9	0.08730	0.05772	2.24
10	0.08370	0.05092	2.27
11	0.08010	0.04412	2.30
12	0.07830	0.04072	2.31
13	0.08370	0.05092	2.27
14	0.06940	0.02390	2.39
15	0.07650	0.03731	2.33
16	0.06940	0.02390	2.39
17	0.06940	0.02390	2.39
18	0.07650	0.03731	2.33
19	0.06940	0.02390	2.39
20	0.08370	0.05092	2.27
21	0.08550	0.05432	2.26
22	0.08730	0.05772	2.24
23	0.08550	0.05432	2.26
24	0.08550	0.05432	2.26
25	0.08370	0.05092	2.27
26	0.08550	0.05432	2.26
27	0.08370	0.05092	2.27
28	0.08550	0.05432	2.26
29	0.08910	0.06112	2.23
30	0.08730	0.05772	2.24
31	0.08910	0.06112	2.23
32	0.08730	0.05772	2.24
33	0.09630	0.07472	2.18
34	0.09810	0.07812	2.17

TABLE 12. $\varphi = 60$ and $\alpha = 10.00$ Degrees

TAP	P/P_0	C_P	LOCAL MACH
1	0.39980	0.64814	1.22
2	0.59520	1.01731	0.89
3	0.09630	0.07472	2.18
4	0.14110	0.15937	1.94
5	0.09270	0.06792	2.21
6	0.08550	0.05432	2.26
7	0.08010	0.04412	2.30
8	0.07830	0.04072	2.31
9	0.07650	0.03731	2.33
10	0.07300	0.03070	2.36
11	0.06940	0.02390	2.31
12	0.06760	0.02050	2.41
13	0.06400	0.01370	2.44
14	0.05860	0.00350	2.50
15	0.06400	0.01370	2.44
16	0.05860	0.00350	2.50
17	0.05860	0.00350	2.50
18	0.05860	0.00350	2.50
19	0.05860	0.00350	2.50
20	0.06760	0.02050	2.41
21	0.06940	0.02390	2.39
22	0.07110	0.02711	2.37
23	0.06940	0.02390	2.39
24	0.07110	0.02711	2.37
25	0.06940	0.02390	2.39
26	0.07110	0.02711	2.37
27	0.06940	0.02390	2.39
28	0.06940	0.02390	2.39
29	0.07300	0.03070	2.36
30	0.07300	0.03070	2.36
31	0.07300	0.03070	2.36
32	0.07300	0.03070	2.36
33	0.08550	0.05432	2.26
34	0.08370	0.05092	2.27

TABLE 13. $\varphi = 60$ and $\alpha = 15.00$ Degrees

TAP	P/P_0	C_p	LOCAL MACH
1	0.36440	0.58126	1.29
2	0.60490	1.03564	0.88
3	0.08980	0.06244	2.22
4	0.15440	0.18449	1.88
5	0.08260	0.04884	2.28
6	0.07900	0.04204	2.31
7	0.07360	0.03184	2.35
8	0.07190	0.02862	2.37
9	0.07010	0.02522	2.38
10	0.06470	0.01502	2.44
11	0.02290	-0.06395	2.45
12	0.06110	0.00822	2.47
13	0.05750	0.00142	2.51
14	0.05750	0.00142	2.51
15	0.05930	0.00482	2.49
16	0.05750	0.00142	2.51
17	0.05570	-0.00198	2.53
18	0.05750	0.00142	2.51
19	0.05750	0.00142	2.51
20	0.06290	0.01162	2.45
21	0.06470	0.01502	2.44
22	0.06650	0.01842	2.42
23	0.06470	0.01502	2.44
24	0.06650	0.01842	2.42
25	0.06470	0.01502	2.44
26	0.06650	0.01842	2.42
27	0.06470	0.01502	2.44
28	0.06470	0.01502	2.44
29	0.06650	0.01842	2.42
30	0.06470	0.01502	2.44
31	0.06650	0.01842	2.42
32	0.06650	0.01842	2.42
33	0.06170	0.00935	2.14
34	0.09870	0.07942	2.17

TABLE 14. φ = 90 and α = -10.00 Degrees

TAP	P/P$_0$	C$_P$	LOCAL MACH
1	0.46490	0.77113	1.11
2	0.46320	0.76792	1.11
3	0.11320	0.10665	2.08
4	0.11500	0.11005	2.07
5	0.10420	0.08965	2.13
6	0.09700	0.07605	2.18
7	0.09350	0.06943	2.20
8	0.09170	0.06603	2.21
9	0.08990	0.06263	2.22
10	0.08450	0.05243	2.26
11	0.08450	0.05243	2.26
12	0.08270	0.04903	2.28
13	0.07910	0.04223	2.31
14	0.07910	0.04223	2.31
15	0.08090	0.04563	2.29
16	0.07730	0.03883	2.32
17	0.07910	0.04223	2.31
18	0.07730	0.03883	2.32
19	0.07910	0.04223	2.31
20	0.08270	0.04903	2.28
21	0.08810	0.05923	2.24
22	0.08990	0.06263	2.22
23	0.08810	0.05923	2.24
24	0.08810	0.05923	2.24
25	0.08630	0.05583	2.25
26	0.08810	0.05923	2.24
27	0.08630	0.05583	2.25
28	0.08810	0.05923	2.24
29	0.08990	0.06263	2.22
30	0.08450	0.05243	2.26
31	0.08810	0.05923	2.24
32	0.08630	0.05583	2.25
33	0.10060	0.08285	2.15
34	0.09880	0.07945	2.17

TABLE 15. $\varphi = 90$ and $\alpha = 0$ Degrees

TAP	P/P_0	C_P	LOCAL MACH
1	0.51130	0.85880	1.03
2	0.50410	0.84520	1.04
3	0.10680	0.09456	2.11
4	0.11280	0.10590	2.08
5	0.10030	0.08228	2.16
6	0.09310	0.06868	2.20
7	0.08590	0.05507	2.25
8	0.08410	0.05167	2.27
9	0.08050	0.04487	2.30
10	0.07690	0.03807	2.32
11	0.07520	0.03486	2.34
12	0.06980	0.02466	2.39
13	0.06800	0.02126	2.41
14	0.06620	0.01785	2.42
15	0.06800	0.02126	2.41
16	0.06620	0.01785	2.42
17	0.06620	0.01785	2.42
18	0.06440	0.01445	2.44
19	0.06620	0.01785	2.42
20	0.06980	0.02466	2.41
21	0.07520	0.03486	2.34
22	0.07695	0.03816	2.32
23	0.07520	0.03486	2.34
24	0.07340	0.03146	2.35
25	0.07340	0.03146	2.35
26	0.07520	0.03486	2.34
27	0.07520	0.03486	2.34
28	0.07520	0.03486	2.34
29	0.07690	0.03807	2.32
30	0.07690	0.03807	2.32
31	0.07690	0.03807	2.32
32	0.07690	0.03807	2.32
33	0.08230	0.04827	2.28
34	0.08230	0.04827	2.28

TABLE 16. $\varphi = 90$ and $\alpha = 5.00$ Degrees

TAP	P/P_0	C_P	LOCAL MACH
1	0.51130	0.85880	1.03
2	0.50050	0.83839	1.05
3	0.10930	0.09928	2.10
4	0.11100	0.10250	2.09
5	0.09670	0.07548	2.18
6	0.09130	0.06528	2.22
7	0.08230	0.04827	2.28
8	0.08050	0.04487	2.30
9	0.07690	0.03807	2.33
10	0.07340	0.03146	2.36
11	0.06980	0.02466	2.39
12	0.06980	0.02466	2.46
13	0.06260	0.01105	2.46
14	0.06260	0.01105	2.46
15	0.06440	0.01445	2.44
16	0.06080	0.00765	2.47
17	0.06080	0.00765	2.47
18	0.06080	0.00765	2.47
19	0.06080	0.00765	2.47
20	0.06440	0.01445	2.44
21	0.07340	0.03146	2.36
22	0.07160	0.02806	2.37
23	0.06980	0.02466	2.39
24	0.07160	0.02806	2.37
25	0.06980	0.02466	2.39
26	0.07160	0.02806	2.37
27	0.06980	0.02466	2.39
28	0.06980	0.02466	2.39
29	0.07160	0.02806	2.37
30	0.07160	0.02806	2.37
31	0.07340	0.03146	2.36
32	0.07340	0.03146	2.36
33	0.07690	0.03807	2.33
34	0.07870	0.04147	2.31

TABLE 17. $\varphi = 90$ and $\alpha = 10.00$ Degrees

TAP	P/P_0	C_p	LOCAL MACH
1	0.48740	0.81364	1.06
2	0.47860	0.79702	1.08
3	0.10530	0.09173	2.12
4	0.10710	0.09513	2.11
5	0.10720	0.09532	2.11
6	0.08560	0.05451	2.26
7	0.07840	0.04090	2.31
8	0.07480	0.03410	2.34
9	0.07120	0.02730	2.37
10	0.06760	0.02050	2.41
11	0.06400	0.01370	2.44
12	0.06220	0.01030	2.46
13	0.05680	0.00009	2.52
14	0.05500	-0.00331	2.54
15	0.05680	0.00009	2.52
16	0.05500	-0.00331	2.54
17	0.05320	-0.00671	2.56
18	0.05320	-0.00671	2.56
19	0.05320	-0.00671	2.56
20	0.05860	0.00350	2.50
21	0.06400	0.01370	2.44
22	0.06400	0.01370	2.44
23	0.06220	0.01030	2.46
24	0.06220	0.01030	2.46
25	0.06040	0.00690	2.48
26	0.06220	0.01030	2.46
27	0.06040	0.00690	2.48
28	0.06220	0.01030	2.46
29	0.06400	0.01370	2.44
30	0.06220	0.01030	2.46
31	0.06400	0.01370	2.44
32	0.06400	0.01370	2.44
33	0.07120	0.02730	2.37
34	0.06940	0.02390	2.39

TABLE 18. $\varphi = 90$ and $\alpha = -15.00$ Degrees

TAP	P/P_0	C_P	LOCAL MACH
1	0.46960	0.78001	1.10
2	0.46060	0.76301	1.11
3	0.10530	0.09173	2.12
4	0.10710	0.09513	2.11
5	0.09090	0.06452	2.22
6	0.08380	0.05111	2.27
7	0.07480	0.03410	2.34
8	0.07300	0.03070	2.36
9	0.06940	0.02390	2.37
10	0.06400	0.01370	2.44
11	0.05880	0.00387	2.50
12	0.05870	0.00368	2.50
13	0.05500	-0.00331	2.54
14	0.05150	-0.00992	2.58
15	0.05510	-0.00312	2.54
16	0.05150	-0.00992	2.58
17	0.04970	-0.01332	2.61
18	0.05150	-0.00992	2.58
19	0.05150	-0.00992	2.58
20	0.05500	-0.00331	2.54
21	0.06220	0.01030	2.46
22	0.06040	0.00690	2.48
23	0.06220	0.01030	2.46
24	0.05870	0.00368	2.50
25	0.05680	0.00009	2.52
26	0.05870	0.00368	2.50
27	0.05680	0.00009	2.52
28	0.05680	0.00009	2.52
29	0.05870	0.00368	2.50
30	0.05680	0.00009	2.52
31	0.05870	0.00368	2.50
32	0.05680	0.00009	2.52
33	0.06940	0.02390	2.39
34	0.06580	0.01710	2.42

TABLE 19. $\varphi = 0$ and $\alpha = -5.00$ Degrees

TAP	P/P_0	C_P	LOCAL MACH
1	0.58700	1.00182	0.91
2	0.41650	0.67969	1.19
3	0.13650	0.15067	1.96
4	0.09700	0.07605	2.18
5	0.11650	0.11289	2.06
6	0.10940	0.09947	2.10
7	0.10240	0.08625	2.14
8	0.09700	0.07605	2.18
9	0.09350	0.06943	2.20
10	0.08810	0.05923	2.24
11	0.08090	0.04563	2.29
12	0.07550	0.03543	2.34
13	0.07010	0.02522	2.38
14	0.06830	0.02182	2.40
15	0.06830	0.02182	2.40
16	0.06650	0.01842	2.42
17	0.06050	0.00709	2.48
18	0.06650	0.01842	2.42
19	0.06050	0.00709	2.48
20	0.07010	0.02522	2.38
21	0.07190	0.02862	2.37
22	0.07370	0.03202	2.35
23	0.07190	0.02862	2.37
24	0.07370	0.03202	2.35
25	0.07370	0.03202	2.35
26	0.07550	0.03543	2.34
27	0.07370	0.03202	2.35
28	0.07370	0.03202	2.35
29	0.07910	0.04223	2.31
30	0.07910	0.04223	2.31
31	0.07730	0.03883	2.32
32	0.07730	0.03883	2.32
33	0.07730	0.03883	2.32
34	0.08090	0.04563	2.29

TABLE 20. $\varphi = 0$ and $\alpha = -10.00$ Degrees

TAP	P/P_c	C_P	LOCAL MACH
1	0.66770	1.15429	0.78
2	0.33570	0.52703	1.35
3	0.16700	0.20830	1.83
4	0.08090	0.04563	2.29
5	0.14910	0.17448	1.90
6	0.19010	0.25194	1.94
7	0.12580	0.13046	2.00
8	0.16690	0.20811	1.83
9	0.11320	0.10665	2.08
10	0.10780	0.09645	2.11
11	0.09700	0.07605	2.18
12	0.08810	0.05923	2.24
13	0.07550	0.03543	2.34
14	0.07190	0.02862	2.37
15	0.07370	0.03202	2.35
16	0.07010	0.02522	2.38
17	0.07010	0.02522	2.38
18	0.07010	0.02522	2.38
19	0.07010	0.02522	2.38
20	0.07370	0.03202	2.35
21	0.07910	0.04223	2.31
22	0.07550	0.03543	2.34
23	0.07550	0.03543	2.34
24	0.07730	0.03883	2.32
25	0.07730	0.03883	2.32
26	0.07910	0.04223	2.31
27	0.07730	0.03883	2.32
28	0.07910	0.04223	2.31
29	0.08450	0.05243	2.27
30	0.08630	0.05583	2.25
31	0.08100	0.04582	2.29
32	0.08100	0.04582	2.29
33	0.07190	0.02862	2.37
34	0.07370	0.03202	2.35

TABLE 21. $\varphi = 0$ and $\alpha = -15.00$ Degrees

TAP	P/P_0	C_P	LOCAL MACH
1	0.73060	1.27313	0.68
2	0.27470	0.41178	1.49
3	0.22090	0.31014	1.64
4	0.07370	0.03202	2.35
5	0.19040	0.25251	1.74
6	0.18140	0.23551	1.77
7	0.17240	0.21850	1.81
8	0.17060	0.21510	1.81
9	0.15990	0.19489	1.85
10	0.15450	0.18468	1.88
11	0.13470	0.14727	1.96
12	0.12220	0.12366	2.03
13	0.09700	0.07605	2.18
14	0.09170	0.06603	2.21
15	0.08990	0.06263	2.22
16	0.08630	0.05583	2.25
17	0.08450	0.05243	2.26
18	0.08630	0.05583	2.25
19	0.08450	0.05243	2.26
20	0.08810	0.05923	2.24
21	0.08990	0.06263	2.22
22	0.08990	0.06263	2.22
23	0.08810	0.05923	2.24
24	0.08990	0.06263	2.22
25	0.09530	0.07283	2.19
26	0.10240	0.08625	2.14
27	0.09530	0.07283	2.19
28	0.10250	0.08644	2.14
29	0.10420	0.08965	2.13
30	0.10250	0.08644	2.14
31	0.09890	0.07964	2.16
32	0.10060	0.08285	2.15
33	0.10420	0.08965	2.13
34	0.10420	0.08965	2.13

TABLE 22. $\varphi = -30$ and $\alpha = -2.75$ Degrees

TAP	P/P_0	C_P	LOCAL MACH
1	0.58160	0.99162	0.91
2	0.45240	0.74752	1.13
3	0.12580	0.13046	2.01
4	0.09520	0.07265	2.19
5	0.11140	0.10325	2.09
6	0.10420	0.08965	2.13
7	0.09520	0.07265	2.19
8	0.09170	0.06603	2.21
9	0.08810	0.05923	2.24
10	0.08270	0.04903	2.28
11	0.07730	0.03883	2.32
12	0.07190	0.02862	2.37
13	0.06650	0.01842	2.42
14	0.06440	0.01445	2.44
15	0.06650	0.01842	2.42
16	0.06290	0.01162	2.45
17	0.06290	0.01162	2.45
18	0.06290	0.01162	2.45
19	0.06470	0.01502	2.43
20	0.06830	0.02182	2.40
21	0.07190	0.02862	2.37
22	0.07190	0.02862	2.37
23	0.07190	0.02862	2.37
24	0.07190	0.02862	2.37
25	0.07190	0.02862	2.37
26	0.07370	0.03202	2.35
27	0.07190	0.02862	2.37
28	0.07370	0.03202	2.35
29	0.07730	0.03883	2.32
30	0.07730	0.03883	2.32
31	0.07550	0.03543	2.34
32	0.07550	0.03543	2.34
33	0.07370	0.03202	2.35
34	0.07730	0.03883	2.32

TABLE 23. $\varphi = -30$ and $\alpha = -7.75$ Degrees

TAP	P/P_0	C_P	LOCAL MACH
1	0.63180	1.08646	0.84
2	0.36980	0.59146	1.28
3	0.15300	0.18185	1.88
4	0.08300	0.04960	2.28
5	0.13470	0.14720	1.96
6	0.12400	0.12706	2.02
7	0.11140	0.10325	2.09
8	0.10600	0.09305	2.12
9	0.10060	0.08285	2.15
10	0.09700	0.07605	2.18
11	0.08630	0.05583	2.25
12	0.07730	0.03883	2.32
13	0.07010	0.02522	2.38
14	0.06650	0.01842	2.42
15	0.06830	0.02182	2.40
16	0.06470	0.01502	2.43
17	0.06470	0.01502	2.43
18	0.06650	0.01842	2.42
19	0.06470	0.01502	2.43
20	0.06830	0.02182	2.40
21	0.07370	0.03202	2.35
22	0.07190	0.02862	2.37
23	0.07010	0.02522	2.38
24	0.07190	0.02862	2.37
25	0.07190	0.02862	2.37
26	0.07370	0.03202	2.35
27	0.07010	0.02522	2.38
28	0.07370	0.03202	2.35
29	0.07730	0.03883	2.32
30	0.07730	0.03883	2.32
31	0.07370	0.03202	2.32
32	0.07370	0.03202	2.35
33	0.07010	0.02522	2.38
34	0.07190	0.02862	2.37

TABLE 24. $\varphi = -30$ and $\alpha = -12.75$ Degrees

TAP	P/P_0	C_P	LOCAL MACH
1	0.68700	1.19076	0.75
2	0.29840	0.45656	1.44
3	0.18710	0.24628	1.75
4	0.07050	0.02508	2.38
5	0.16200	0.19885	1.85
6	0.15300	0.18185	1.88
7	0.14410	0.16503	1.92
8	0.13870	0.15483	1.95
9	0.13150	0.14123	1.98
10	0.12610	0.13103	2.01
11	0.10820	0.09721	2.11
12	0.09740	0.07680	2.17
13	0.07950	0.04298	2.30
14	0.07410	0.03278	2.35
15	0.07410	0.03278	2.35
16	0.07050	0.02598	2.38
17	0.07050	0.02598	2.38
18	0.07230	0.02938	2.36
19	0.07410	0.03278	2.35
20	0.07770	0.03958	2.32
21	0.07950	0.04298	2.30
22	0.07770	0.03958	2.32
23	0.07770	0.03958	2.32
24	0.07950	0.04298	2.30
25	0.07950	0.04298	2.30
26	0.08130	0.04638	2.29
27	0.08130	0.04638	2.29
28	0.09020	0.06320	2.22
29	0.08840	0.05980	2.24
30	0.08840	0.05980	2.24
31	0.08300	0.04960	2.28
32	0.08300	0.04960	2.28
33	0.06510	0.01578	2.43
34	0.06330	0.01238	2.45

TABLE 25. $\varphi = 0$ and $\alpha = 2.05$ Degrees

TAP	P/P_0	C_p	LOCAL MACH
1	0.49620	0.83027	1.05
2	0.58410	0.99634	0.91
3	0.11270	0.10571	2.08
4	0.13550	0.14879	1.96
5	0.12830	0.13518	2.00
6	0.13370	0.14538	1.97
7	0.11030	0.10117	2.14
8	0.11570	0.11138	2.06
9	0.11140	0.10325	2.09
10	0.07440	0.03335	2.35
11	0.07080	0.02655	2.38
12	0.06730	0.01993	2.41
13	0.06190	0.00973	2.46
14	0.06010	0.00633	2.48
15	0.06190	0.00973	2.46
16	0.06010	0.00633	2.48
17	0.05830	0.00293	2.50
18	0.06010	0.00633	2.48
19	0.06190	0.00973	2.46
20	0.06730	0.01993	2.41
21	0.07080	0.02655	2.38
22	0.07260	0.02995	2.36
23	0.07080	0.02655	2.38
24	0.07260	0.02995	2.36
25	0.07260	0.02995	2.36
26	0.07440	0.03335	2.35
27	0.07260	0.02995	2.36
28	0.07440	0.03335	2.35
29	0.07620	0.03675	2.33
30	0.07620	0.03675	2.33
31	0.07620	0.03675	2.33
32	0.07620	0.03675	2.33
33	0.07802	0.04019	2.32
34	0.07802	0.04019	2.32

TABLE 26. $\varphi = 0$ and $\alpha = -7.75$ Degrees

TAP	P/P_0	C_R	LOCAL MACH
1	0.65410	1.12860	0.80
2	0.35620	0.56576	1.31
3	0.18750	0.24703	1.75
4	0.09060	0.06395	2.22
5	0.13720	0.15200	1.95
6	0.15880	0.19281	1.86
7	0.09960	0.08096	2.16
8	0.10850	0.09777	2.11
9	0.10310	0.08757	2.14
10	0.09960	0.08096	2.16
11	0.08700	0.05715	2.25
12	0.07980	0.04355	2.30
13	0.06900	0.02314	2.39
14	0.06550	0.01653	2.43
15	0.06730	0.01993	2.41
16	0.06370	0.01313	2.45
17	0.06370	0.01313	2.45
18	0.06370	0.01313	2.45
19	0.06550	0.01653	2.43
20	0.06900	0.02314	2.39
21	0.07080	0.02655	2.38
22	0.07080	0.02655	2.38
23	0.07080	0.02655	2.38
24	0.07260	0.02995	2.36
25	0.07440	0.03335	2.35
26	0.07620	0.03675	2.33
27	0.07440	0.03335	2.35
28	0.07620	0.03675	2.33
29	0.07980	0.04355	2.30
30	0.08160	0.04695	2.29
31	0.07800	0.04015	2.32
32	0.07620	0.03675	2.33
33	0.07080	0.02655	2.38
34	0.07260	0.02995	2.36

TABLE 27. $\varphi = 0$ and $\alpha = -12.75$ Degrees

TAP	P/P_0	C_P	LOCAL MACH
1	0.72880	1.26973	0.69
2	0.28010	0.42198	1.48
3	0.23520	0.33715	1.60
4	0.07910	0.04223	2.31
5	0.17240	0.21850	1.81
6	0.21730	0.30333	1.65
7	0.13110	0.14047	1.98
8	0.15450	0.18468	1.88
9	0.14910	0.17448	1.90
10	0.14370	0.16428	1.92
11	0.12220	0.12366	2.03
12	0.11320	0.10665	2.08
13	0.08990	0.06263	2.23
14	0.08450	0.05243	2.27
15	0.08270	0.04903	2.28
16	0.07910	0.04223	2.31
17	0.07910	0.04223	2.31
18	0.08090	0.04563	2.29
19	0.07910	0.04223	2.31
20	0.08450	0.05243	2.27
21	0.08630	0.05583	2.25
22	0.08630	0.05583	2.25
23	0.08450	0.05243	2.27
24	0.08630	0.05583	2.25
25	0.09350	0.06943	2.20
26	0.09010	0.06301	2.22
27	0.09700	0.07605	2.18
28	0.10420	0.08965	2.13
29	0.09880	0.07945	2.16
30	0.10060	0.08285	2.15
31	0.09350	0.06943	2.20
32	0.09700	0.07605	2.18
33	0.06670	0.01880	2.42
34	0.06670	0.01880	2.42

Appendix C

PT. MUGU WIND-TUNNEL TEST DATA

To check the pressure data obtained from the MIT wind-tunnel tests, conducted for NOTS in connection with heat-transfer studies on a blunt body at angle of attack, wind-tunnel tests were made also at the University of Southern California Engineering Center's supersonic wind tunnel at the Aerodynamic Test Laboratory, NMC, Pt. Mugu. At this facility, test schedules similar to those used in the MIT experiments were used to reproduce, to some extent, the original experimental conditions. The results of the Pt. Mugu wind-tunnel tests are recorded in Tables 28 through 43 in this appendix as follows:

φ = circumferential angular position measured from downward station
α = angle of attack
tap = pressure tap station
p = static pressure
C_p = pressure coefficient

TABLE 28. $\varphi = 0$ Degree

TAP	ALPHA = 0.0		ALPHA = 5.0		ALPHA = 9.2	
	P	C_P	P	C_P	P	C_P
1	9.094	0.7878	7.625	0.6359	6.523	0.5219
2	9.329	0.8121	10.830	0.9673	12.103	1.0989
3	2.324	0.0878	2.980	0.1556	3.633	0.2231
4	1.274	-0.0208	1.550	0.0077	1.933	0.0473
5	1.354	-0.0125	1.515	0.0041	1.848	0.0385
6	2.274	0.0826	1.725	0.0258	1.373	-0.0106
7	2.059	0.0604	1.630	0.0160	1.358	-0.0121
8	1.984	0.0526	1.575	0.0103	1.343	-0.0137
9	1.824	0.0361	1.480	0.0005	1.303	-0.0178
10	1.804	0.0340	1.475	-0.	1.308	-0.0173
11	1.739	0.0273	1.465	-0.0010	1.313	-0.0168
12	1.714	0.0247	1.440	-0.0036	1.298	-0.0183
13	1.544	0.0071	1.325	-0.0155	1.213	-0.0271
14	1.459	-0.0016	1.260	-0.0222	1.178	-0.0308
15	1.259	-0.0223	1.110	-0.0377	1.058	-0.0432
16	1.264	-0.0218	1.145	-0.0341	1.273	-0.0209
17	1.274	-0.0208	1.165	-0.0320	1.313	-0.0168
18	1.294	-0.0187	1.195	-0.0289	1.313	-0.0168
19	1.304	-0.0177	1.220	-0.0264	1.348	-0.0132
20	1.324	-0.0156	1.255	-0.0227	1.353	-0.0127
21	1.329	-0.0151	1.285	-0.0196	1.378	-0.0101
22	1.344	-0.0135	1.335	-0.0145	1.403	-0.0075
23	1.344	-0.0135	1.345	-0.0134	1.433	-0.0044
24	1.359	-0.0120	1.370	-0.0108	1.438	-0.0039
25	1.364	-0.0115	1.380	-0.0098	1.463	-0.0013
26	1.369	-0.0110	1.405	-0.0072	1.098	-0.0390
27	1.404	-0.0073	1.415	-0.0062	1.143	-0.0344
28	1.444	-0.0032	1.445	-0.0031	1.198	-0.0287
29	1.434	-0.0042	1.440	-0.0036	1.223	-0.0261
30	1.459	-0.0016	1.460	-0.0015	1.258	-0.0225
31	1.439	-0.0037	1.445	-0.0031	1.438	-0.0039
32	1.494	0.0020	1.495	0.0021	1.493	0.0018
33	1.554	0.0082	1.480	0.0005	1.408	-0.0070
34	1.504	0.0030	1.500	0.0026	1.438	-0.0039

TABLE 29. φ = 15 Degrees

TAP	ALPHA = 0.0 P	ALPHA = 0.0 C_P	ALPHA = 5.0 P	ALPHA = 5.0 C_P	ALPHA = 9.2 P	ALPHA = 9.2 C_P
1	9.054	0.7836	7.674	0.6410	6.597	0.5296
2	9.279	0.8069	10.789	0.9631	12.007	1.0889
3	2.309	0.0862	2.959	0.1534	3.597	0.2194
4	1.264	-0.0219	1.544	0.0071	1.902	0.0441
5	1.354	-0.0126	1.499	0.0025	1.807	0.0343
6	2.274	0.0826	1.739	0.0273	1.402	-0.0076
7	2.059	0.0603	1.634	0.0164	1.382	-0.0097
8	1.979	0.0521	1.579	0.0107	1.362	-0.0117
9	1.819	0.0355	1.479	0.0004	1.307	-0.0174
10	1.799	0.0334	1.484	0.0009	1.312	-0.0169
11	1.739	0.0272	1.464	-0.0011	1.307	-0.0174
12	1.714	0.0247	1.444	-0.0032	1.292	-0.0190
13	1.544	0.0071	1.329	-0.0151	1.207	-0.0278
14	1.459	-0.0017	1.259	-0.0223	1.182	-0.0303
15	1.259	-0.0224	1.104	-0.0384	1.022	-0.0469
16	1.269	-0.0213	1.139	-0.0347	1.087	-0.0402
17	1.274	-0.0208	1.154	-0.0332	1.117	-0.0371
18	1.294	-0.0188	1.194	-0.0290	1.167	-0.0319
19	1.304	-0.0177	1.234	-0.0249	1.197	-0.0288
20	1.324	-0.0157	1.264	-0.0218	1.232	-0.0252
21	1.329	-0.0151	1.274	-0.0208	1.232	-0.0252
22	1.344	-0.0136	1.324	-0.0156	1.272	-0.0210
23	1.344	-0.0136	1.329	-0.0151	1.262	-0.0221
24	1.359	-0.0120	1.364	-0.0115	1.287	-0.0195
25	1.359	-0.0120	1.369	-0.0110	1.272	-0.0210
26	1.369	-0.0110	1.394	-0.0084	1.282	-0.0200
27	1.399	-0.0079	1.404	-0.0073	1.257	-0.0226
28	1.439	-0.0038	1.434	-0.0042	1.277	-0.0205
29	1.429	-0.0048	1.419	-0.0058	1.242	-0.0241
30	1.454	-0.0022	1.439	-0.0037	1.262	-0.0221
31	1.439	-0.0038	1.429	-0.0047	1.237	-0.0247
32	1.494	0.0019	1.469	-0.0006	1.312	-0.0169
33	1.529	0.0055	1.419	-0.0058	1.247	-0.0236
34	1.484	0.0009	1.449	-0.0027	1.272	-0.0210

TABLE 30. φ = 30 Degrees

TAP	ALPHA = 0.0		ALPHA = 5.0		ALPHA = 9.2	
	P	C_P	P	C_P	P	C_P
1	8.991	0.7771	7.742	0.6480	6.795	0.5501
2	9.206	0.7994	10.612	0.9448	11.720	1.0593
3	2.296	0.0849	2.867	0.1439	3.445	0.2037
4	1.251	-0.0232	1.477	0.0002	1.765	0.0300
5	1.341	-0.0138	1.447	-0.0029	1.670	0.0202
6	2.211	0.0761	1.762	0.0297	1.455	-0.0021
7	2.046	0.0590	1.662	0.0193	1.405	-0.0072
8	1.961	0.0502	1.597	0.0126	1.380	-0.0098
9	1.811	0.0347	1.492	0.0017	1.310	-0.0171
10	1.791	0.0327	1.482	0.0007	1.300	-0.0181
11	1.731	0.0265	1.462	-0.0013	1.275	-0.0207
12	1.701	0.0234	1.437	-0.0039	1.255	-0.0227
13	1.531	0.0058	1.317	-0.0163	1.165	-0.0320
14	1.451	-0.0025	1.257	-0.0225	1.140	-0.0346
15	1.251	-0.0232	1.087	-0.0401	0.960	-0.0532
16	1.266	-0.0216	1.127	-0.0360	1.005	-0.0486
17	1.266	-0.0216	1.147	-0.0339	1.025	-0.0465
18	1.286	-0.0195	1.192	-0.0293	1.060	-0.0429
19	1.296	-0.0185	1.212	-0.0272	1.095	-0.0393
20	1.316	-0.0164	1.237	-0.0246	1.130	-0.0357
21	1.316	-0.0164	1.232	-0.0251	1.125	-0.0362
22	1.336	-0.0144	1.272	-0.0210	1.160	-0.0326
23	1.331	-0.0149	1.277	-0.0205	1.150	-0.0336
24	1.351	-0.0128	1.317	-0.0163	1.160	-0.0326
25	1.356	-0.0123	1.322	-0.0158	1.140	-0.0346
26	1.361	-0.0118	1.347	-0.0132	1.135	-0.0351
27	1.381	-0.0097	1.367	-0.0112	1.065	-0.0424
28	1.421	-0.0056	1.392	-0.0086	1.060	-0.0429
29	1.421	-0.0056	1.387	-0.0091	0.970	-0.0522
30	1.441	-0.0035	1.392	-0.0086	0.940	-0.0553
31	1.431	-0.0045	1.387	-0.0091	0.845	-0.0651
32	1.481	0.0006	1.437	-0.0039	0.840	-0.0656
33	1.491	0.0016	1.387	-0.0091	0.865	-0.0631
34	1.466	-0.0009	1.397	-0.0081	0.835	-0.0662

TABLE 31. φ = 45 Degrees

TAP	ALPHA = 0.0 P	ALPHA = 0.0 C_P	ALPHA = 5.0 P	ALPHA = 5.0 C_P	ALPHA = 9.2 P	ALPHA = 9.2 C_P
1	8.984	0.7770	7.952	0.6702	7.139	0.5861
2	9.249	0.8045	10.407	0.9242	11.289	1.0155
3	2.309	0.0864	2.777	0.1348	3.219	0.1805
4	1.259	-0.0222	1.412	-0.0065	1.594	0.0124
5	1.344	-0.0134	1.387	-0.0090	1.479	0.0005
6	2.194	0.0745	1.837	0.0375	1.559	0.0088
7	2.039	0.0585	1.717	0.0251	1.474	-0.
8	1.954	0.0497	1.657	0.0189	1.434	-0.0041
9	1.804	0.0341	1.537	0.0065	1.334	-0.0145
10	1.779	0.0315	1.522	0.0049	1.314	-0.0165
11	1.724	0.0259	1.477	0.0002	1.259	-0.0222
12	1.699	0.0233	1.467	-0.0008	1.244	-0.0238
13	1.524	0.0052	1.342	-0.0137	1.139	-0.0347
14	1.444	-0.0031	1.272	-0.0209	1.084	-0.0403
15	1.244	-0.0238	1.097	-0.0390	0.914	-0.0579
16	1.259	-0.0222	1.132	-0.0354	0.939	-0.0553
17	1.269	-0.0212	1.142	-0.0344	0.924	-0.0569
18	1.284	-0.0196	1.177	-0.0308	0.944	-0.0548
19	1.294	-0.0186	1.197	-0.0287	0.964	-0.0528
20	1.314	-0.0165	1.212	-0.0272	0.999	-0.0491
21	1.319	-0.0160	1.207	-0.0277	1.014	-0.0476
22	1.339	-0.0140	1.242	-0.0240	1.064	-0.0424
23	1.334	-0.0145	1.247	-0.0235	1.079	-0.0409
24	1.349	-0.0129	1.277	-0.0204	1.114	-0.0372
25	1.354	-0.0124	1.282	-0.0199	1.114	-0.0372
26	1.359	-0.0119	1.302	-0.0178	1.114	-0.0372
27	1.384	-0.0093	1.337	-0.0142	1.089	-0.0398
28	1.419	-0.0057	1.362	-0.0116	1.094	-0.0393
29	1.424	-0.0052	1.362	-0.0116	1.069	-0.0419
30	1.439	-0.0036	1.377	-0.0101	1.069	-0.0419
31	1.429	-0.0046	1.372	-0.0106	1.069	-0.0419
32	1.489	0.0015	1.432	-0.0044	1.094	-0.0393
33	1.489	0.0015	1.392	-0.0085	1.084	-0.0403
34	1.464	-0.0010	1.402	-0.0075	1.079	-0.0409

TABLE 32. φ = 60 Degrees

TAP	ALPHA = 0.0		ALPHA = 5.0		ALPHA = 9.2	
	P	C_P	P	C_P	P	C_P
1	9.017	0.7804	8.249	0.7010	7.604	0.6343
2	9.277	0.8073	10.109	0.8935	10.714	0.9561
3	2.327	0.0882	2.649	0.1216	2.944	0.1521
4	1.267	-0.0215	1.339	-0.0140	1.419	-0.0057
5	1.357	-0.0121	1.329	-0.0150	1.299	-0.0181
6	2.212	0.0763	1.944	0.0486	1.729	0.0264
7	2.052	0.0597	1.804	0.0341	1.594	0.0124
8	1.967	0.0509	1.734	0.0269	1.529	0.0057
9	1.812	0.0349	1.599	0.0129	1.409	-0.0067
10	1.792	0.0328	1.579	0.0109	1.379	-0.0098
11	1.737	0.0272	1.529	0.0057	1.319	-0.0160
12	1.712	0.0246	1.504	0.0031	1.279	-0.0202
13	1.537	0.0065	1.374	-0.0103	1.159	-0.0326
14	1.452	-0.0023	1.299	-0.0181	1.084	-0.0403
15	1.252	-0.0230	1.104	-0.0383	0.894	-0.0600
16	1.267	-0.0215	1.139	-0.0347	0.904	-0.0590
17	1.277	-0.0204	1.134	-0.0352	0.874	-0.0621
18	1.297	-0.0184	1.159	-0.0326	0.864	-0.0631
19	1.302	-0.0178	1.179	-0.0305	0.859	-0.0636
20	1.322	-0.0158	1.199	-0.0284	0.859	-0.0636
21	1.327	-0.0153	1.189	-0.0295	0.839	-0.0657
22	1.352	-0.0127	1.219	-0.0264	0.864	-0.0631
23	1.347	-0.0132	1.214	-0.0269	0.879	-0.0616
24	1.362	-0.0116	1.244	-0.0238	0.939	-0.0553
25	1.367	-0.0111	1.234	-0.0248	0.989	-0.0502
26	1.372	-0.0106	1.249	-0.0233	1.024	-0.0466
27	1.397	-0.0080	1.289	-0.0191	1.074	-0.0414
28	1.432	-0.0044	1.324	-0.0155	1.094	-0.0393
29	1.422	-0.0054	1.329	-0.0150	1.109	-0.0378
30	1.457	-0.0018	1.354	-0.0124	1.124	-0.0362
31	1.437	-0.0039	1.379	-0.0098	1.149	-0.0336
32	1.517	0.0044	1.409	-0.0067	1.219	-0.0264
33	1.487	0.0013	1.374	-0.0103	1.194	-0.0290
34	1.472	-0.0002	1.384	-0.0093	1.204	-0.0279

TABLE 33. φ = 75 Degrees

	ALPHA = 0.0		ALPHA = 5.0		ALPHA = 9.2	
TAP	P	C_P	P	C_P	P	C_P
1	8.972	0.7758	8.548	0.7319	8.183	0.6941
2	9.237	0.8032	9.703	0.8514	9.998	0.8819
3	2.327	0.0882	2.493	0.1054	2.643	0.1209
4	1.262	-0.0220	1.268	-0.0214	1.243	-0.0239
5	1.357	-0.0121	1.253	-0.0229	1.058	-0.0431
6	2.202	0.0753	2.048	0.0593	1.948	0.0490
7	2.047	0.0592	1.913	0.0454	1.783	0.0319
8	1.957	0.0499	1.833	0.0371	1.683	0.0216
9	1.802	0.0339	1.688	0.0221	1.538	0.0066
10	1.777	0.0313	1.658	0.0190	1.498	0.0024
11	1.727	0.0261	1.598	0.0128	1.438	-0.0038
12	1.707	0.0240	1.563	0.0091	1.403	-0.0074
13	1.532	0.0059	1.418	-0.0058	1.253	-0.0229
14	1.442	-0.0034	1.338	-0.0141	1.163	-0.0322
15	1.242	-0.0240	1.143	-0.0343	0.953	-0.0539
16	1.262	-0.0220	1.158	-0.0327	0.953	-0.0539
17	1.277	-0.0204	1.148	-0.0338	0.908	-0.0586
18	1.292	-0.0189	1.163	-0.0322	0.888	-0.0607
19	1.302	-0.0178	1.178	-0.0307	0.868	-0.0627
20	1.322	-0.0158	1.188	-0.0296	0.858	-0.0638
21	1.327	-0.0153	1.178	-0.0307	0.818	-0.0679
22	1.347	-0.0132	1.203	-0.0281	0.803	-0.0695
23	1.347	-0.0132	1.198	-0.0286	0.773	-0.0726
24	1.362	-0.0116	1.218	-0.0265	0.763	-0.0736
25	1.362	-0.0116	1.198	-0.0286	0.723	-0.0777
26	1.372	-0.0106	1.208	-0.0276	0.718	-0.0783
27	1.397	-0.0080	1.223	-0.0260	0.848	-0.0648
28	1.432	-0.0044	1.253	-0.0229	0.943	-0.0550
29	1.427	-0.0049	1.268	-0.0214	1.068	-0.0421
30	1.457	-0.0018	1.293	-0.0188	1.093	-0.0395
31	1.467	-0.0008	1.328	-0.0151	1.153	-0.0333
32	1.482	0.0008	1.373	-0.0105	1.198	-0.0286
33	1.497	0.0023	1.318	-0.0162	1.178	-0.0307
34	1.457	-0.0018	1.333	-0.0146	1.183	-0.0302

TABLE 34. φ = 90 Degrees

TAP	ALPHA = 0.0		ALPHA = 5.0		ALPHA = 9.2	
	P	C_p	P	C_p	P	C_p
1	8.991	0.7777	8.878	0.7661	8.789	0.7569
2	9.271	0.8067	14.333	1.3305	9.294	0.8091
3	2.331	0.0886	2.338	0.0894	2.369	0.0926
4	1.261	-0.0221	1.198	-0.0285	1.074	-0.0414
5	1.361	-0.0117	1.203	-0.0280	0.874	-0.0621
6	2.196	0.0746	2.158	0.0708	2.159	0.0709
7	2.041	0.0586	2.008	0.0552	1.979	0.0522
8	1.956	0.0498	1.933	0.0475	1.864	0.0403
9	1.796	0.0333	1.773	0.0309	1.709	0.0243
10	1.776	0.0312	1.738	0.0273	1.664	0.0196
11	1.721	0.0255	1.683	0.0216	1.589	0.0119
12	1.696	0.0229	1.643	0.0175	1.549	0.0078
13	1.521	0.0048	1.473	-0.0001	1.384	-0.0093
14	1.441	-0.0035	1.388	-0.0089	1.294	-0.0186
15	1.241	-0.0242	1.178	-0.0306	1.064	-0.0424
16	1.261	-0.0221	1.198	-0.0285	1.059	-0.0429
17	1.276	-0.0205	1.178	-0.0306	1.004	-0.0486
18	1.291	-0.0190	1.193	-0.0291	0.984	-0.0507
19	1.301	-0.0179	1.203	-0.0280	0.964	-0.0528
20	1.316	-0.0164	1.218	-0.0265	0.959	-0.0533
21	1.316	-0.0164	1.198	-0.0285	0.924	-0.0569
22	1.341	-0.0138	1.213	-0.0270	0.909	-0.0585
23	1.341	-0.0138	1.203	-0.0280	0.889	-0.0605
24	1.356	-0.0123	1.223	-0.0260	0.879	-0.0616
25	1.361	-0.0117	1.203	-0.0280	0.844	-0.0652
26	1.371	-0.0107	1.213	-0.0270	0.834	-0.0662
27	1.391	-0.0086	1.208	-0.0275	0.789	-0.0709
28	1.426	-0.0050	1.233	-0.0249	0.779	-0.0719
29	1.421	-0.0055	1.228	-0.0254	0.754	-0.0745
30	1.446	-0.0029	1.253	-0.0229	0.769	-0.0729
31	1.461	-0.0014	1.238	-0.0244	0.829	-0.0667
32	1.471	-0.0004	1.368	-0.0110	0.934	-0.0559
33	1.501	0.0027	1.268	-0.0213	0.994	-0.0497
34	1.466	-0.0009	1.283	-0.0198	0.959	-0.0533

TABLE 35. $\varphi = 105$ Degrees

TAP	ALPHA = 0.0		ALPHA = 5.0		ALPHA = 9.2	
	P	C_p	P	C_p	P	C_p
1	9.059	0.7880	9.294	0.8124	9.645	0.8488
2	9.334	0.8166	8.844	0.7657	8.515	0.7315
3	2.334	0.0898	2.174	0.0732	2.095	0.0649
4	1.264	-0.0213	1.129	-0.0353	0.945	-0.0544
5	1.364	-0.0109	1.194	-0.0285	0.730	-0.0768
6	2.209	0.0768	2.329	0.0893	2.480	0.1049
7	2.044	0.0597	2.144	0.0701	2.265	0.0826
8	1.964	0.0514	2.059	0.0612	2.140	0.0696
9	1.804	0.0348	1.899	0.0446	1.985	0.0535
10	1.784	0.0327	1.859	0.0405	1.940	0.0488
11	1.724	0.0265	1.789	0.0332	1.855	0.0400
12	1.699	0.0239	1.759	0.0301	1.830	0.0374
13	1.534	0.0067	1.579	0.0114	1.610	0.0146
14	1.449	-0.0021	1.474	0.0005	1.500	0.0032
15	1.264	-0.0213	1.264	-0.0213	1.270	-0.0207
16	1.274	-0.0202	1.264	-0.0213	1.250	-0.0228
17	1.279	-0.0197	1.244	-0.0233	1.200	-0.0280
18	1.294	-0.0182	1.254	-0.0223	1.190	-0.0290
19	1.299	-0.0176	1.254	-0.0223	1.185	-0.0295
20	1.314	-0.0161	1.264	-0.0213	1.180	-0.0300
21	1.314	-0.0161	1.254	-0.0223	1.155	-0.0326
22	1.334	-0.0140	1.264	-0.0213	1.135	-0.0347
23	1.334	-0.0140	1.259	-0.0218	1.110	-0.0373
24	1.354	-0.0119	1.264	-0.0213	1.105	-0.0378
25	1.364	-0.0109	1.244	-0.0233	1.070	-0.0415
26	1.374	-0.0099	1.259	-0.0218	1.065	-0.0420
27	1.394	-0.0078	1.239	-0.0239	1.030	-0.0456
28	1.429	-0.0041	1.259	-0.0218	1.020	-0.0467
29	1.424	-0.0047	1.244	-0.0233	0.985	-0.0503
30	1.449	-0.0021	1.259	-0.0218	0.980	-0.0508
31	1.484	0.0015	1.279	-0.0197	0.960	-0.0529
32	1.504	0.0036	1.299	-0.0176	0.965	-0.0524
33	1.504	0.0036	1.254	-0.0223	1.015	-0.0472
34	1.464	-0.0005	1.269	-0.0208	0.925	-0.0565

TABLE 36. $\varphi = 120$ Degrees

TAP	ALPHA = 0.0		ALPHA = 5.0		ALPHA = 9.2	
	P	C_P	P	C_P	P	C_P
1	9.042	0.7862	9.700	0.8545	10.277	0.9144
2	9.292	0.8121	8.555	0.7356	7.922	0.6699
3	2.337	0.0901	2.085	0.0639	1.902	0.0449
4	1.257	-0.0221	1.105	-0.0378	0.897	-0.0594
5	1.367	-0.0106	1.230	-0.0249	0.962	-0.0527
6	2.217	0.0776	2.485	0.1054	2.747	0.1326
7	2.052	0.0605	2.290	0.0852	2.492	0.1061
8	1.967	0.0516	2.185	0.0743	2.382	0.0947
9	1.807	0.0350	2.010	0.0561	2.202	0.0760
10	1.782	0.0324	1.980	0.0530	2.157	0.0714
11	1.722	0.0262	1.900	0.0447	2.072	0.0625
12	1.687	0.0226	1.870	0.0416	2.027	0.0579
13	1.532	0.0065	1.680	0.0218	1.817	0.0361
14	1.452	-0.0018	1.565	0.0099	1.687	0.0226
15	1.267	-0.0210	1.340	-0.0134	1.412	-0.0060
16	1.272	-0.0205	1.340	-0.0134	1.407	-0.0065
17	1.277	-0.0200	1.320	-0.0155	1.357	-0.0117
18	1.292	-0.0184	1.330	-0.0145	1.362	-0.0112
19	1.292	-0.0184	1.325	-0.0150	1.357	-0.0117
20	1.307	-0.0169	1.330	-0.0145	1.357	-0.0117
21	1.307	-0.0169	1.310	-0.0165	1.327	-0.0148
22	1.327	-0.0148	1.320	-0.0155	1.322	-0.0153
23	1.327	-0.0148	1.310	-0.0165	1.297	-0.0179
24	1.347	-0.0127	1.335	-0.0140	1.292	-0.0184
25	1.362	-0.0112	1.320	-0.0155	1.272	-0.0205
26	1.377	-0.0096	1.340	-0.0134	1.277	-0.0200
27	1.382	-0.0091	1.305	-0.0171	1.232	-0.0246
28	1.422	-0.0049	1.315	-0.0160	1.232	-0.0246
29	1.417	-0.0054	1.310	-0.0165	1.197	-0.0283
30	1.447	-0.0023	1.320	-0.0155	1.207	-0.0272
31	1.447	-0.0023	1.315	-0.0160	1.197	-0.0283
32	1.547	0.0080	1.380	-0.0093	1.207	-0.0272
33	1.497	0.0028	1.300	-0.0176	1.152	-0.0330
34	1.462	-0.0008	1.290	-0.0186	1.232	-0.0246

TABLE 37. φ = 135 Degrees

TAP	ALPHA = 0.0		ALPHA = 5.0		ALPHA = 9.2	
	P	C_p	P	C_p	P	C_p
1	9.041	0.7861	10.000	0.8853	10.845	0.9730
2	9.326	0.8157	8.250	0.7037	7.405	0.6160
3	2.351	0.0915	1.995	0.0545	1.720	0.0259
4	1.261	-0.0216	1.090	-0.0394	0.910	-0.0581
5	1.366	-0.0107	1.275	-0.0202	1.115	-0.0368
6	2.211	0.0770	2.620	0.1193	3.000	0.1589
7	2.051	0.0604	2.410	0.0975	2.740	0.1319
8	1.961	0.0510	2.295	0.0856	2.635	0.1209
9	1.806	0.0349	2.105	0.0659	2.435	0.1001
10	1.781	0.0323	2.080	0.0633	2.395	0.0960
11	1.721	0.0261	2.005	0.0555	2.305	0.0867
12	1.691	0.0230	1.980	0.0529	2.255	0.0815
13	1.536	0.0069	1.760	0.0301	2.040	0.0591
14	1.456	-0.0014	1.650	0.0187	1.905	0.0451
15	1.261	-0.0216	1.405	-0.0067	1.580	0.0114
16	1.266	-0.0211	1.425	-0.0047	1.565	0.0098
17	1.271	-0.0206	1.395	-0.0078	1.525	0.0057
18	1.276	-0.0201	1.400	-0.0073	1.540	0.0073
19	1.281	-0.0196	1.400	-0.0073	1.540	0.0073
20	1.296	-0.0180	1.395	-0.0078	1.545	0.0079
21	1.296	-0.0180	1.375	-0.0098	1.505	0.0036
22	1.321	-0.0154	1.395	-0.0078	1.505	0.0036
23	1.326	-0.0149	1.380	-0.0093	1.480	0.0010
24	1.346	-0.0128	1.400	-0.0073	1.485	0.0015
25	1.361	-0.0113	1.390	-0.0083	1.460	-0.0010
26	1.371	-0.0102	1.410	-0.0062	1.475	0.0005
27	1.386	-0.0087	1.370	-0.0104	1.435	-0.0036
28	1.431	-0.0040	1.395	-0.0078	1.435	-0.0036
29	1.416	-0.0055	1.365	-0.0109	1.405	-0.0067
30	1.441	-0.0029	1.400	-0.0073	1.425	-0.0047
31	1.466	-0.0004	1.400	-0.0073	1.410	-0.0062
32	1.536	0.0069	1.435	-0.0036	1.425	-0.0047
33	1.496	0.0027	1.400	-0.0073	1.360	-0.0114
34	1.456	-0.0014	1.415	-0.0057	1.390	-0.0083

TABLE 38. φ = 150 Degrees

TAP	ALPHA = 0.0		ALPHA = 5.0		ALPHA = 9.2	
	P	C_p	P	C_p	P	C_p
1	8.955	0.7768	10.220	0.9081	11.327	1.0231
2	9.215	0.8038	7.940	0.6715	6.967	0.5706
3	2.315	0.0877	1.890	0.0436	1.567	0.0101
4	1.285	-0.0192	1.090	-0.0394	0.982	-0.0506
5	1.350	-0.0124	1.320	-0.0156	1.142	-0.0340
6	2.180	0.0737	2.730	0.1308	3.237	0.1834
7	2.035	0.0586	2.505	0.1074	2.962	0.1549
8	1.945	0.0493	2.380	0.0944	2.857	0.1440
9	1.790	0.0332	2.170	0.0726	2.642	0.1217
10	1.765	0.0306	2.155	0.0711	2.617	0.1191
11	1.705	0.0244	2.075	0.0628	2.502	0.1071
12	1.680	0.0218	2.055	0.0607	2.477	0.1046
13	1.530	0.0062	1.830	0.0374	2.237	0.0796
14	1.445	-0.0026	1.715	0.0254	2.117	0.0672
15	1.245	-0.0233	1.465	-0.0005	1.752	0.0293
16	1.250	-0.0228	1.480	0.0010	1.752	0.0293
17	1.250	-0.0228	1.445	-0.0026	1.717	0.0257
18	1.255	-0.0223	1.460	-0.0010	1.732	0.0272
19	1.260	-0.0218	1.450	-0.0021	1.727	0.0267
20	1.275	-0.0202	1.450	-0.0021	1.727	0.0267
21	1.280	-0.0197	1.430	-0.0041	1.687	0.0226
22	1.300	-0.0176	1.450	-0.0021	1.687	0.0226
23	1.310	-0.0166	1.440	-0.0031	1.662	0.0200
24	1.330	-0.0145	1.470	-0.	1.677	0.0215
25	1.340	-0.0135	1.450	-0.0021	1.657	0.0195
26	1.350	-0.0124	1.470	-0.	1.672	0.0215
27	1.370	-0.0104	1.435	-0.0036	1.622	0.0158
28	1.405	-0.0067	1.450	-0.0021	1.632	0.0169
29	1.405	-0.0067	1.435	-0.0036	1.617	0.0153
30	1.440	-0.0031	1.480	0.0010	1.657	0.0195
31	1.450	-0.0021	1.465	-0.0005	1.602	0.0137
32	1.495	0.0026	1.505	0.0036	1.642	0.0179
33	1.480	0.0010	1.420	-0.0052	1.567	0.0101
34	1.435	-0.0036	1.465	-0.0005	1.592	0.0127

TABLE 39. φ = 165 Degrees

TAP	ALPHA = 0.0 P	C_P	ALPHA = 5.0 P	C_P	ALPHA = 9.2 P	C_P
1	9.003	0.7815	10.411	0.9276	11.620	1.0531
2	9.248	0.8069	7.781	0.6547	6.690	0.5416
3	2.323	0.0884	1.841	0.0384	1.490	0.0021
4	1.293	-0.0184	1.121	-0.0363	1.040	-0.0446
5	1.353	-0.0122	1.361	-0.0114	1.265	-0.0213
6	2.193	0.0750	2.816	0.1396	3.405	0.2007
7	2.048	0.0599	2.581	0.1152	3.130	0.1722
8	1.953	0.0501	2.446	0.1012	3.000	0.1587
9	1.793	0.0334	2.236	0.0794	2.775	0.1354
10	1.778	0.0319	2.231	0.0789	2.745	0.1323
11	1.728	0.0267	2.131	0.0685	2.630	0.1203
12	1.703	0.0241	2.106	0.0659	2.615	0.1188
13	1.538	0.0070	1.901	0.0447	2.340	0.0903
14	1.453	-0.0018	1.791	0.0332	2.210	0.0768
15	1.253	-0.0226	1.511	0.0042	1.860	0.0405
16	1.253	-0.0226	1.521	0.0052	1.865	0.0410
17	1.248	-0.0231	1.491	0.0021	1.835	0.0379
18	1.258	-0.0220	1.506	0.0037	1.870	0.0415
19	1.258	-0.0220	1.481	0.0011	1.855	0.0399
20	1.278	-0.0200	1.486	0.0016	1.845	0.0389
21	1.278	-0.0200	1.461	-0.0010	1.810	0.0353
22	1.308	-0.0168	1.486	0.0016	1.815	0.0358
23	1.313	-0.0163	1.481	0.0011	1.800	0.0342
24	1.333	-0.0143	1.516	0.0047	1.835	0.0379
25	1.343	-0.0132	1.506	0.0037	1.800	0.0342
26	1.348	-0.0127	1.526	0.0057	1.835	0.0379
27	1.368	-0.0106	1.491	0.0021	1.785	0.0327
28	1.403	-0.0070	1.501	0.0032	1.790	0.0332
29	1.408	-0.0065	1.491	0.0021	1.785	0.0327
30	1.458	-0.0013	1.551	0.0083	1.850	0.0394
31	1.458	-0.0013	1.506	0.0037	1.755	0.0296
32	1.498	0.0028	1.556	0.0089	1.810	0.0353
33	1.508	0.0039	1.486	0.0016	1.750	0.0290
34	1.453	-0.0018	1.531	0.0063	1.770	0.0311

TABLE 40. $\varphi = 180$ Degrees

TAP	ALPHA = 0.0		ALPHA = 5.0		ALPHA = 9.2	
	P	C_P	P	C_P	P	C_P
1	8.777	0.7581	10.263	0.9122	11.548	1.0455
2	9.032	0.7846	7.533	0.6290	6.423	0.5138
3	2.137	0.0692	1.633	0.0168	1.293	-0.0184
4	1.092	-0.0392	0.938	-0.0552	0.893	-0.0599
5	1.167	-0.0314	1.193	-0.0288	1.178	-0.0303
6	2.002	0.0552	2.653	0.1227	3.298	0.1896
7	1.852	0.0396	2.418	0.0983	3.018	0.1605
8	1.767	0.0308	2.278	0.0838	2.863	0.1445
9	1.602	0.0137	2.078	0.0630	2.638	0.1211
10	1.597	0.0132	2.053	0.0604	2.603	0.1175
11	1.552	0.0085	1.963	0.0511	2.508	0.1076
12	1.527	0.0059	1.943	0.0490	2.478	0.1045
13	1.352	-0.0122	1.748	0.0288	2.193	0.0750
14	1.272	-0.0205	1.638	0.0174	2.093	0.0646
15	1.067	-0.0418	1.333	-0.0143	1.733	0.0272
16	1.072	-0.0413	1.348	-0.0127	1.753	0.0293
17	1.057	-0.0428	1.323	-0.0153	1.708	0.0246
18	1.067	-0.0418	1.333	-0.0143	1.753	0.0293
19	1.072	-0.0413	1.308	-0.0168	1.738	0.0277
20	1.092	-0.0392	1.308	-0.0168	1.728	0.0267
21	1.092	-0.0392	1.283	-0.0194	1.673	0.0210
22	1.117	-0.0366	1.308	-0.0168	1.693	0.0231
23	1.127	-0.0356	1.298	-0.0179	1.688	0.0226
24	1.147	-0.0335	1.318	-0.0158	1.723	0.0262
25	1.157	-0.0325	1.323	-0.0153	1.683	0.0220
26	1.162	-0.0319	1.333	-0.0143	1.723	0.0262
27	1.187	-0.0294	1.323	-0.0153	1.653	0.0189
28	1.217	-0.0262	1.343	-0.0132	1.673	0.0210
29	1.227	-0.0252	1.343	-0.0132	1.663	0.0200
30	1.277	-0.0200	1.393	-0.0080	1.723	0.0262
31	1.272	-0.0205	1.338	-0.0137	1.623	0.0158
32	1.317	-0.0159	1.383	-0.0091	1.683	0.0220
33	1.312	-0.0164	1.323	-0.0153	1.618	0.0153
34	1.282	-0.0195	1.363	-0.0111	1.653	0.0189

TABLE 41. φ = 225 Degrees

TAP	ALPHA = 0.0 P	ALPHA = 0.0 C_P	ALPHA = 5.0 P	ALPHA = 5.0 C_P	ALPHA = 9.2 P	ALPHA = 9.2 C_P
1	9.031	0.7841	10.128	0.8979	10.940	0.9821
2	9.191	0.8007	8.108	0.6884	7.235	0.5979
3	2.316	0.0876	1.953	0.0500	1.670	0.0207
4	1.266	-0.0213	1.098	-0.0386	0.915	-0.0576
5	1.361	-0.0114	1.273	-0.0205	1.105	-0.0379
6	2.211	0.0767	2.648	0.1221	3.080	0.1669
7	2.046	0.0596	2.418	0.0983	2.775	0.1353
8	1.946	0.0493	2.298	0.0858	2.665	0.1239
9	1.816	0.0358	2.093	0.0646	2.425	0.0990
10	1.791	0.0332	2.058	0.0609	2.385	0.0948
11	1.736	0.0275	1.998	0.0547	2.290	0.0850
12	1.711	0.0249	1.983	0.0531	2.245	0.0803
13	1.546	0.0078	1.778	0.0319	2.045	0.0596
14	1.461	-0.0010	1.668	0.0205	1.930	0.0476
15	1.256	-0.0223	1.403	-0.0070	1.590	0.0124
16	1.266	-0.0213	1.423	-0.0049	1.580	0.0113
17	1.261	-0.0218	1.408	-0.0065	1.545	0.0077
18	1.276	-0.0202	1.418	-0.0054	1.565	0.0098
19	1.276	-0.0202	1.393	-0.0080	1.540	0.0072
20	1.286	-0.0192	1.393	-0.0080	1.535	0.0067
21	1.291	-0.0187	1.373	-0.0101	1.510	0.0041
22	1.316	-0.0161	1.393	-0.0080	1.520	0.0051
23	1.321	-0.0155	1.383	-0.0091	1.485	0.0015
24	1.341	-0.0135	1.408	-0.0065	1.500	0.0030
25	1.356	-0.0119	1.388	-0.0085	1.480	0.0010
26	1.361	-0.0114	1.408	-0.0065	1.490	0.0020
27	1.391	-0.0083	1.368	-0.0106	1.440	-0.0032
28	1.431	-0.0041	1.393	-0.0080	1.450	-0.0021
29	1.406	-0.0067	1.368	-0.0106	1.415	-0.0057
30	1.436	-0.0036	1.388	-0.0085	1.440	-0.0032
31	1.461	-0.0010	1.398	-0.0075	1.420	-0.0052
32	1.526	0.0057	1.453	-0.0018	1.455	-0.0016
33	1.526	0.0057	1.353	-0.0122	1.380	-0.0094
34	1.471	-0.	1.393	-0.0080	1.415	-0.0057

TABLE 42. φ = 270 Degrees

TAP	ALPHA = 0.0		ALPHA = 5.0		ALPHA = 9.2	
	P	C_p	P	C_p	P	C_p
1	8.909	0.7711	8.939	0.7742	8.839	0.7639
2	9.139	0.7950	9.059	0.7867	8.974	0.7779
3	2.309	0.0868	2.274	0.0832	2.284	0.0842
4	1.254	-0.0225	1.184	-0.0298	1.074	-0.0412
5	1.354	-0.0122	1.189	-0.0293	0.854	-0.0640
6	2.189	0.0744	2.194	0.0749	2.219	0.0775
7	2.039	0.0588	2.024	0.0573	2.004	0.0552
8	1.939	0.0485	1.929	0.0474	1.914	0.0459
9	1.774	0.0314	1.749	0.0288	1.709	0.0246
10	1.764	0.0303	1.719	0.0257	1.664	0.0199
11	1.719	0.0257	1.654	0.0189	1.579	0.0111
12	1.699	0.0236	1.629	0.0163	1.534	0.0065
13	1.524	0.0054	1.474	0.0002	1.359	-0.0117
14	1.439	-0.0034	1.384	-0.0091	1.279	-0.0199
15	1.239	-0.0241	1.174	-0.0308	1.049	-0.0438
16	1.254	-0.0225	1.189	-0.0293	1.034	-0.0454
17	1.259	-0.0220	1.164	-0.0319	0.999	-0.0490
18	1.274	-0.0205	1.189	-0.0293	0.989	-0.0500
19	1.279	-0.0199	1.179	-0.0303	0.959	-0.0531
20	1.304	-0.0174	1.184	-0.0298	0.949	-0.0542
21	1.309	-0.0168	1.179	-0.0303	0.919	-0.0573
22	1.329	-0.0148	1.199	-0.0282	0.929	-0.0562
23	1.329	-0.0148	1.194	-0.0288	0.899	-0.0593
24	1.349	-0.0127	1.199	-0.0282	0.894	-0.0599
25	1.354	-0.0122	1.184	-0.0298	0.854	-0.0640
26	1.359	-0.0117	1.199	-0.0282	0.844	-0.0650
27	1.379	-0.0096	1.194	-0.0288	0.784	-0.0713
28	1.414	-0.0060	1.214	-0.0267	0.784	-0.0713
29	1.409	-0.0065	1.214	-0.0267	0.754	-0.0744
30	1.429	-0.0044	1.229	-0.0251	0.759	-0.0739
31	1.429	-0.0044	1.244	-0.0236	0.859	-0.0635
32	1.584	0.0117	1.299	-0.0179	0.894	-0.0599
33	1.519	0.0049	1.289	-0.0189	1.064	-0.0422
34	1.484	0.0013	1.269	-0.0210	1.079	-0.0407

TABLE 43. $\varphi = 315$ Degrees

TAP	ALPHA = 0.0 P	ALPHA = 0.0 C_P	ALPHA = 5.0 P	ALPHA = 5.0 C_P	ALPHA = 9.2 P	ALPHA = 9.2 C_P
1	8.984	0.7789	7.945	0.6712	7.103	0.5839
2	9.194	0.8007	10.235	0.9086	11.113	0.9996
3	2.309	0.0868	2.745	0.1320	3.143	0.1733
4	1.259	-0.0220	1.400	-0.0074	1.583	0.0116
5	1.349	-0.0127	1.380	-0.0095	1.478	0.0007
6	2.204	0.0759	1.850	0.0392	1.583	0.0116
7	2.044	0.0593	1.715	0.0252	1.483	0.0012
8	1.954	0.0500	1.655	0.0190	1.433	-0.0040
9	1.789	0.0329	1.525	0.0055	1.328	-0.0149
10	1.759	0.0298	1.510	0.0040	1.303	-0.0175
11	1.709	0.0246	1.470	-0.0001	1.248	-0.0232
12	1.684	0.0220	1.440	-0.0033	1.218	-0.0263
13	1.524	0.0054	1.320	-0.0157	1.123	-0.0361
14	1.434	-0.0039	1.245	-0.0235	1.058	-0.0429
15	1.234	-0.0246	1.060	-0.0427	0.888	-0.0605
16	1.254	-0.0225	1.110	-0.0375	0.918	-0.0574
17	1.254	-0.0225	1.120	-0.0364	0.918	-0.0574
18	1.274	-0.0205	1.165	-0.0318	0.953	-0.0537
19	1.284	-0.0194	1.170	-0.0313	0.958	-0.0532
20	1.304	-0.0174	1.195	-0.0287	0.988	-0.0501
21	1.309	-0.0168	1.200	-0.0281	1.018	-0.0470
22	1.334	-0.0142	1.230	-0.0250	1.063	-0.0423
23	1.334	-0.0142	1.240	-0.0240	1.083	-0.0403
24	1.349	-0.0127	1.265	-0.0214	1.103	-0.0382
25	1.354	-0.0122	1.270	-0.0209	1.108	-0.0377
26	1.359	-0.0117	1.295	-0.0183	1.108	-0.0377
27	1.379	-0.0096	1.320	-0.0157	1.073	-0.0413
28	1.419	-0.0054	1.350	-0.0126	1.083	-0.0403
29	1.419	-0.0054	1.360	-0.0116	1.068	-0.0418
30	1.434	-0.0039	1.370	-0.0105	1.073	-0.0413
31	1.419	-0.0054	1.365	-0.0110	1.063	-0.0423
32	1.479	0.0008	1.400	-0.0074	1.103	-0.0382
33	1.519	0.0049	1.400	-0.0074	1.138	-0.0346
34	1.469	-0.0002	1.420	-0.0053	1.088	-0.0398

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